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SOME DIFFICULTIES ENCOUNTERED IN THE OPERATION OF PUMPS, AS MET BY THE "POSITIVE PISTON PUMP."

BY JOSIAH DOW.

To raise a column of fluid, power applied with a pump yields directly effective work in overcoming gravity of the mass, and the friction which is indispensable from necessary contact in pipes and pump chamber. These resistances are obvious necessities, with any method we may employ. In practice, however, other resistances are developed, arising from mechanical methods of construction, which absorb power, often to a great degree, where it yields no effective work, while causing much wear and tear.

The reciprocating system has maintained pre-eminence, because by the piston or "plunger" any desired pressure can be directly applied against the column of fluid to be moved. Were it possible to make this action continuous,

without reversals of reciprocation, no resistances would be met in addition to those noted as inseparable from efficient work, and momentum would become an aiding and equalizing force, as it does with the fly-wheel of a steam engine. But reciprocation converts this force into an active resistant.

Water not being compressible to any appreciable extent, and possessing much weight, through its momentum causes serious difficulties in operating reciprocating pumps, which were expressed by the late Mr. H. R. Worthington, to whom we are so much indebted for improvement in pumping machinery, in these words: "A moment's reflection will show that when the motion of a pump changes, the valves are in the wrong relation thereto, and must be immediately changed. For an instant of time, therefore, the resistance is suspended, much as in the case of a gear suddenly reversed and producing 'backlash.'" Again he wrote, when referring to the valves of a pumping engine: "Before one set can be seated and the other lifted, the engine, by a sudden jump, strikes the water heavily and pounds the valves to their seats. Hence, the noise which always has, and always will, to a greater or less degree, mark the self-destructive action of an ordinary reciprocating pump." Mr. Worthington's remedy was to allow the valves to seat themselves by gravity before beginning the return stroke. This necessitated a very low rate of speed and reduced resistance to the extent that would be realized from a body at rest, instead of moving to meet a momentum. He also appears to have used another means for relieving impact, by making the valve openings of such area that water would not flow fast enough to fill the chamber until after the plunger had come to rest; for he writes: "It reaches the end of its stroke and stops—what follows? The water continues to press, by its momentum, into the chamber, filling every inch of space."

A modification of this practice is a well-known necessity with builders and operators of all reciprocating pumps which move large masses of water. Taking ten of the best known pumping engines in this country, we find a speed of only

eight to nineteen revolutions per minute. Indicator cards taken from water cylinders of such pumping engines, show that those which run at the highest rate of this very moderate speed, exhibit clearly the "water hammer" in its sudden resistance against the plunger. Therefore, to lessen this resistance, a low rate of speed must be maintained. Large air chambers are provided for the same purpose; also the passages and valves must be carefully proportioned to a definite rate of speed.

Small reciprocating pumps often run at higher speeds; in such cases there is much vibration and resistance from impact, with great wear and tear; but, as the containing parts are proportionately strong, these difficulties have assumed position as necessary evils, although the concussions and vibrations may often be heard and felt throughout large buildings. That we may reach some idea of the real value of this destructive work, let us examine:

(1) The physical laws which govern reaction, when motion of a body is arrested.

(2) The results of expert tests, exhibiting value of the reaction in pumps.

(3) Mechanical construction of reciprocating pumps, which causes the reactionary resistance.

For the physical laws it will be sufficient to select three well-known authorities:

From Professor Rankine: "Momentum is the product of the mass of a body into its velocity, in units of distance per second."

"The reaction of a retarded body is as the force required to produce the change of velocity."

From Professor Thurston: "Acceleration and retardation of masses in motion can only be produced by doing work upon them, or by causing them to do work."

"Every mass undergoing retardation must perform work, and thus must restore energy previously communicated to it."

From Weisbach: "There can be no action of a force, without an equal and contrary reaction."

Work performed by a moving mass of water, confined in

a pipe, on coming to rest, is represented by the familiar expression—

$$\tfrac{1}{2} M V^2, \text{ or } \frac{W V^2}{2 g}.$$

Where W represents weight of water in the pipe, in pounds; V its final velocity, in feet per second, and g (gravity) 32·2. The quotient is in units of one second, because V and g are in units of one second; therefore, if the mass is brought to rest in a definite time, the rate of doing work through its momentum will be

$$\frac{W V^2}{2 g T},$$

the unit of T being one second.

E. g., a sixteen-inch suction pipe, forty feet long, contains 3,500 pounds of water; take its motion at the moderate speed of three feet per second, which is arrested within the time of change in direction of a pump plunger, running at fifteen revolutions per minute. This would give $15 \times 2 = 30$ movements of the plunger per minute. Allowing for change in direction one-twentieth of each stroke, or one-tenth of a second (time in which water is brought to rest, as shown by many indicator cards, is often less than this), then is—

$$\frac{3500 \times 3^2}{64{\cdot}4 \times 0{\cdot}1} = 4891{\cdot}3 \text{ foot pounds,}$$

the power by which such a column of water resists being brought to rest in one-tenth of a second. To restore the same degree of motion, in a time equal to that which brought it to rest, requires an equal measure of power.

A familiar illustration of these laws is found in the hydraulic ram, which is analogous, in its useful work, to the destructive work of the "water hammer" in a pump, including application of an air chamber to avoid rupture.

The sudden closing of a cock, after drawing water, under pressure, through it, is also a familiar illustration: To avoid risk from heavy impact, the pipe is usually continued above and beyond the cock, that it may contain an air cushion.

It was shown by experiments made in 1884, and published in *Transactions of American Society of Civil Engineers*

for 1885, that arresting a velocity of 5·36 feet per second, with water in pipes aggregating a length of 272 feet, yielded a force of impact, upon being brought to rest, equal to 129·3 pounds per square inch. More than half of the pipe was very small, which would cause retardation through friction, and prevent a free action at the outlet from momentum of the whole mass. The terminal length was but one inch in diameter.

The report made by a board of experts for testing a large pumping engine at Cincinnati, in 1879, shows that "pressure per superficial inch of pump piston, required to open the suction and delivery valves, in addition to frictional resistance of water passages into and out of the pump, was 13·44 pounds (8·816 inlet, 4·624 outlet). Here, the resistances upon the inlet side of a reciprocating pump are shown to be about double the value of those upon the outlet side. In the record of a series of tests, made in 1885, by engineers of the Philadelphia Water Department, upon a direct-action reciprocating pump, with eight-inch pipes, working against a head of 129 feet, and without suctional lift, there is shown a loss of effective indicated horse-power of thirteen per cent. This was apparently sustained at the outlet side.

By comparing expert tests upon eight of the best known water-works pumps, it is shown that loss of force expended within the water cylinders—ascertained by testing the effective work delivered into water mains by the pump—varied from fourteen to twenty-five per cent., and, in one case, twenty-seven per cent. of the indicated horse-power at the engines. Smaller pumps show much greater percentages of loss. The tests were all made with pumping engines built for the best economy of work, and running at low speed for the purpose of avoiding as much as possible the resistances under discussion. None of them were pumps working in connection with direct distribution, which often necessitates very high pressure and greater speed. Acceleration of speed will rapidly increase losses from arrested momentum, notwithstanding the use of air chambers, because they cannot effect avoidance of the reaction; they receive it as would a spring, to immediately restore it again,

and only lend a partial elasticity, near the point of impact, but not in direct line with it. Indicator cards from the water cylinders show this reaction sometimes, in decreasing vibrations, throughout the whole stroke. Occasionally, at high speed of flow, for a moment, resistance to closing the inlet valves is so great that the current passes directly through both sets of valves, and almost completely blocks the mass of water within the cylinder which the plunger is struggling to remove.

We are now brought to mechanical methods of construction which develop these reactions. The usual form of reciprocating pump, for large masses of water, is that in which a plunger, closely fitting in its travel through the cylinder or water chamber, or through a partition dividing it in two, draws the suction and forces the discharge, alternately at each direction of the travel, acting by displacement. Water can pass into one end or the other of the chamber, to follow the retreating plunger, only through valves opening inward, of which two sets, each for its own end, control the current. A similar arrangement is made with the outlet valves, which are placed at the opposite side of the chamber and open outward. As the plunger retreats in its motion, one set of outlet valves close upon their seats, and atmospheric pressure forces the suction column into the space left for it in the chamber through the opposite inlet valves, while the advancing side of the plunger, having first arrested the suction, presses forward the discharge column. A stroke completed, not only is the motion of the plunger stopped, with weight belonging to itself and connecting parts, but also motion of the water on either side of it and in the pipes; momentum directly opposes this stoppage and the immediately following change in motion of the plunger. At this critical moment for the exertion of power by reciprocation, reaction from momentum is only prevented from becoming a destructive blow, through the use of air chambers. This action and reaction are repeated with every stroke.

Were the valves few and large, they would require a full movement from their seats to admit a sufficient volume of

water, and would cause much loss, through "slip," before a closing could be effected. Consequently they are often small and numerous, with but little lift, to secure quick closing. The partition containing them, when they are closed, offers a complete impediment to the flow, and when open, they remain directly in the way of a subdivided current, while the partition is still an obstruction, together causing not only friction in proportion to the velocity of flow, but also conflicting and churning counter currents, as the streams impinge against the valves, to be deflected radially at sharp angles and to come in contact with each other.

Because impact from momentum increases as the square of the velocity, the limit of speed at which a reciprocating pump, handling large masses of water, can be run safely and economically, is soon reached. This necessitates the use of much larger pumps, at much lower speed, than would be necessary were momentum an aid instead of an obstruction.

The *centrifugal* system of pumping completely avoids obstruction by valves, and develops no concussions through resistance to momentum. Consequently, it permits the movement of large volumes with high rates of speed. A centrifugal pump, however, as the name sufficiently indicates, does not apply power directly to the lifting and moving forward of a column of fluid, and unless water flows to it, or the pipe is first filled, it will draw no suction beyond a very trifling height. The power necessary to drive it increases in a much greater ratio than the heights of delivery. A well-known maker of these pumps has given the following rule for determining the application of power to them: "The amount of power necessary is a function of the height to be attained, multiplied by its square root, or $h \sqrt{h} = \sqrt{h^3}$."

E. g., a pump requires ten horse-power to raise water six feet. It will require, if the height is increased to fifty-four feet, $9 \times \sqrt{9} \times 10 = 270$ horse-power, and not simply the original power multiplied by nine, which would be ninety horse-power.

Although centrifugal pumps depend, for efficient work, upon a high rate of speed, yet there is a limit of speed beyond which their efficiency decreases. This limit, for the outer ends of the fans, is stated by different makers to be from twelve to about twenty-five feet per second. By comparing the best authorities regarding the efficiency of work done by these pumps, we find it to vary from twenty-four to sixty per cent. of the whole power applied, when working against the moderate lift at which they perform their best duty: this for small sizes is about fifteen feet; very large sizes carry their efficiency to higher lifts.

A centrifugal pump is the same in principle, and essentially in construction, as a fan blower. The well-known disproportion of power to useful effect in running fan blowers, for any but a very low pressure of air, is repeated with the pump, except that the pump, as it deals with greater mass, has the advantage of momentum. Discharge from the blower may be completely stopped by a moderate obstruction, notwithstanding a rapid movement of the fans. With the pump, water moving at high speed, through its momentum, would prevent such obstruction without great resistance; but, let the discharge opening be firmly closed and then full motion may set up, while water can fill the pump, but none be discharged from it, and there will be but little force developed from movement of the fans, for they, with the water contained within their periphery, then form a nearly solid and balanced mass, meeting but little resistance to its motion other than that caused by friction with the surrounding parts. This will illustrate the reason why there is always a limit of lift beyond which a centrifugal pump can yield no efficient duty and at last effect no discharge at all. The fact that a fan blower can increase or decrease the pressure of air only within a pound to the square inch, at its best work, sufficiently accounts for the inability of a centrifugal pump to draw its own suction without priming.

Pumps which have been known under the general title of "Rotaries," also avoid, in most of their methods of construction, reaction from momentum and resistance from

valves. They contain one or more sets of rotary vanes or buckets; sometimes intermoving with each other in a similar manner to that of the teeth of gears; sometimes running concentrically with the chamber, like a paddle-wheel in its box; and sometimes sliding in and out of a hub or drum having its periphery in contact, or nearly so, with one side of the chamber. Provision is usually made for automatically closing a radial section of the passage or passages through which the vanes or buckets move, in such manner that they shall not be obstructed, while the current can be carried around through the open portions from the inlet, placed at the outer circumference of the chamber, to the discharge at the opposite side.

There have been various modifications of these general designs, but the greater part of them involve similar principles. The volume of water moved by them is relatively large, but they have not competed successfully with the reciprocating system. There have been several causes for this; such as the difficulties, with their peculiarities of construction, in making their action positive enough without great loss through friction; the paddling effect only of the buckets or vanes following each other, and, when they intergear, the loss of action and the conflicting currents at the retreating parts of the rotation; "pocketing" of water and consequent resistance against the vanes when passing the closed portion of the chamber—often quite serious; a sharp deflection of the current at both inlet and outlet; also, resistance to the inflow, caused by receiving it against centrifugal force, which, with high speeds, becomes a serious obstruction, and the outlet is rarely at a tangent to the circumference of motion, as with centrifugal pumps. Such, and other causes, have prevented economy in power, and many of these pumps, when under full duty, develop troublesome concussions, at even moderately high rates of speed, resulting in much wear and tear.

In 1885 a series of tests were made by the Philadelphia Water Department, upon one of the most successful of the large-volume rotary pumps then in use. Water flowed to the pump, therefore no suctional lift was carried. The

static head to be overcome was about 129 feet. The results were as follows:

Test.	Revolutions Per Minute.	Theoretical Discharge. Gallons.	Actual Discharge. Gallons.	Per Cent Attained.	Indicated Horse-Power.	Effective Horse-Power Calculated from Water Raised.	Per Cent. Effectual Horse Power.
A	20·3	101·5	11·3	10·8	4·36	0·33	8·
X	86·6	433·	452·	104·4	23·06	14 6	63·3
Y	104·7	523·5	536·	102·3	29·82	17 65	59·2

It will be seen that at the lowest speed, A, the effectual percentage of result was very small, in both volume of water and power used. This was doubtless caused by pressure from the column to be raised, 55·86 pounds to the square inch, which was sufficient to cause much loss of water, at this low speed, through the loosely fitted moving parts of the pump, while they were obliged to rotate against the pressure. At the next rate of speed, X, a very different result is attained. The speed has now become sufficient to bring momentum into a useful relation to the flow, which is increased even beyond what displacement in the chamber would indicate. The power applied has also greatly increased in effectiveness. Both appear to have reached their best efficiency.

At the last rate of speed, *Y*, new conditions come into action, and the efficiency in both volume and power is again decreased. This is caused by peculiarities of construction. The speed has increased enough to bring centrifugal force, at the inlet, with the sharp angle at both openings, to bear against the current; also enough to cause an impact of pocketed water against the vanes. These resistances, and consequent loss of power would, doubtless, have grown at a rapidly increasing ratio with higher rates of speed. At the most effective velocity, the loss sustained in effective power was 36·7 per cent.

As percussive action and loss of power, beyond its necessary application to overcome gravity and the small percentage of friction in properly arranged pipes, appear, as we have seen, to arise with the systems considered, except the centrifugal, from structural causes, is it possible to avoid these losses, and the destructive strains which accompany them, by practical changes in construction? Obstructed momentum and excessive friction from subdivision, with conflicting currents, caused by necessity for valves and their sustaining partition, to control the changes in direction of the applied power, are the chief causes of disturbance with reciprocation. We have seen, however, with the other two systems, that momentum may be made a friend instead of an enemy; but they do not exhibit the definite character of work sustained by the reciprocating pumps, which depends upon direct application of power to the piston, or plunger, acting by displacement within its chamber; it is, therefore, evident that in the construction of a pump for full efficiency, this feature must be retained. But it cannot reciprocate without rapidly increasing reaction from momentum; its motion must be in one direction, and this can only be about an axis within the bounds of the chamber. It must still retain full control of displacement, as when in reciprocation, but having made a friend of momentum, it may safely attain a high rate of speed, and thus greatly increase its capacity. Speed will develop centrifugal force, which must also be prevented from becoming an enemy; it may be an aid. To accomplish this, the inlet or suction must be around the axis of motion, as with a centrifugal pump, and the outlet at the periphery of the moving parts as nearly as possible in line with a tangent produced from them. The inflow, being around the axis, will pass between it and the piston, and may be carried into the centre of the pump through a cylinder which will be, in effect, a revolving continuation of the suction pipe, upon which the piston may be placed, and around the outside of which will be the chamber, although annular in shape, practically the same, for action of the piston, as that contained in the reciprocating pump. Centrifugal force will now aid in filling the

chamber, the flow being outward from the revolving cylinder, much as water passes from centre to periphery of a centrifugal pump, except that there will be but one opening, and that placed so that it may fill the chamber through

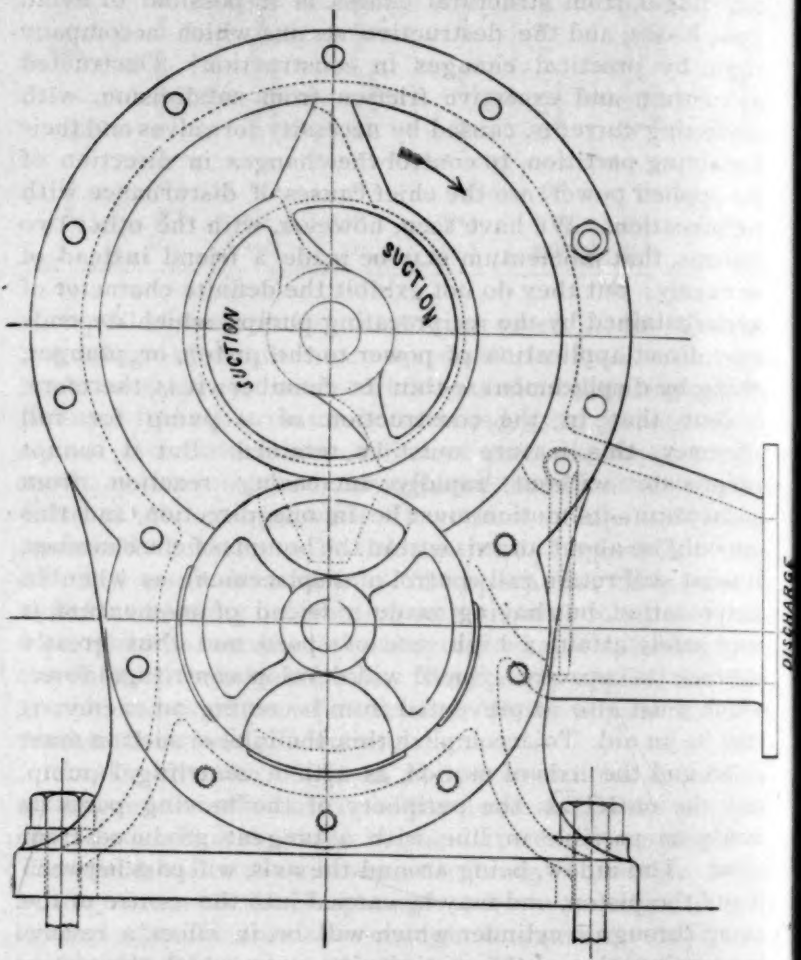


FIG. 1.

the retreating side of the piston, while its advancing side forces the discharge. Without reaction, there can be no action; therefore, no work can be done by the piston, unless the annular chamber be provided with a partition, com-

pletely closing a section of it, to stand in its office as does the head of the cylinder with a reciprocating pump. It must be so constructed as to permit a passage of the piston, without friction, or impact from entrapped water, and to close immediately and firmly behind it. This is effected by a revolving abutment in rolling contact with the cylinder, to which the piston is attached, and with a portion cut away through which it may pass. One piston as described, moving about a central axis, would be unbalanced; therefore, we have two annular chambers, each with its own piston, one balancing the other, and all parts of the pump must have their movement by revolution, and be balanced in action. This construction avoids valves. Water, owing to its momentum and consequent persistence of flow, will not require any, even while the piston passes the abutment. To draw the suction, however, particularly from a considerable depth, the pump then being filled only with air, which is exceedingly elastic, a valve is needed at the outlet to hold the gain in vacuum attained by each stroke of the pistons, until the flow of water is established, when, being hinged at the top, it moves from its seat and can be fastened entirely out of the way, leaving an unobstructed channel. Having secured a free and continuous flow through the pump, which has enlisted as its assistants all the physical forces involved, it will need no air chamber, and will safely attain any desirable rate of speed, against any desirable pressure, with full efficiency of power.

The pump thus described and herewith illustrated in its working parts (see sectional views, *Figs. 1*, *2* and *3*), is now being introduced by the Kensington Engine Works, limited, of Philadelphia, under the name of the "Positive Piston Pump." It has repeatedly been put into practical and daily use, with both large and small volumes, high and low lifts, and shows great economy of power, with steady and quiet flow, at high or low speeds. It can be run for moderate lifts without frictional contact of the working parts, the water itself, in grooves, supplying a packing, and momentum preventing slip, or it can be packed with a self-lubricating packing to prevent slip at any speed or pressure. It

will readily establish its own suction, through use of the suction valve in the discharge, and yet leave the passage perfectly free for the flow of water. It is a small pump, relatively to the large volume of fluid moving through it, which may be increased with every accession of speed.

The same construction, with little modification, has been used as a pressure blower and air compressor, with very satisfactory results. It has the great advantage not only of fast movement, but no trouble arising from condensed and entrapped water.

ALUMINIUM.

By Sir Henry Roscoe, M.P., D.C.L., LL.D., F.R.S.

[*A Discourse delivered at the Royal Institution, London, Friday, May 3, 1889.*]

Chemists of many lands have contributed to our knowledge of the metal aluminium. Davy, in 1807, tried in vain to reduce alumina by means of the electric current. Oerstedt, the Dane, in 1824, pointed out that the metal could be obtained by treating the chloride with an alkali metal; this was accomplished in Germany by Wöhler in 1827, and more completely in 1845, whilst in 1854 Bunsen showed how the metal can be obtained by electrolysis. But it is to France, by the hands of Henri St. Claire Deville, in the same year, that the honor belongs of having first prepared aluminium in a state of purity, and of obtaining it on a scale which enabled its valuable properties to be recognized and made available, and the bar of "silver-white metal from clay," was one of the chemical wonders in the first Paris Exhibition of 1855. Now England and America step in, and I have this evening to relate the important changes which further investigation has effected in the metallurgy of aluminium. The process suggested by Oerstedt, carried out by Wöhler, and modified by Deville, remains in principle unchanged. The metal is prepared, as before, by a

reduction of the double chloride of aluminium and sodium, by means of metallic sodium in presence of cryolite; and it is, therefore, not so much a description of a new reaction as of improvements of old ones of which I have to speak.

I may perhaps be allowed to remind my hearers that more than thirty-three years ago, Mr. Barlow, then Secretary to the Institution, delivered a discourse, in the presence of M. Deville, on the properties and mode of preparation of aluminium, then a novelty. He stated that the metal was then sold at the rate of £3 per ounce, and the exhibition of a small ingot, cast in the laboratory by M. Deville, was considered remarkable. As indicating the progress since made, I may remark that the metal is now sold at twenty shillings per pound, and manufactured by the ton, by the Aluminium Company, at their works at Oldbury, near Birmingham. The improvements which have been made in this manufacture by the zeal and energy of Mr. Castner, an American metallurgist, are of so important a character, that the process may properly be termed the Deville-Castner process.

The production of aluminium previous to 1887, probably did not exceed 10,000 pounds per annum, whilst the price at that time was very high. To attain even this production required that at least 100,000 pounds of double chloride, and 40,000 pounds of sodium should be manufactured annually. From these figures an idea of the magnitude of the undertaking assumed by the Aluminium Company may be estimated, when we learn that they erected works having an annual producing capacity of 100,000 pounds of aluminium. To accomplish this, required not only that at least 400,000 pounds of sodium, 800,000 pounds of chlorine, and 1,000,000 pounds of double chloride, should be annually manufactured, but in addition that each of these materials should be produced at a very low cost, in order to enable the metal to be sold at twenty shillings per pound.

Annexed is a sketch plan of the works, which now cover a space of nearly five acres. They are divided into five separate departments, viz:

(1) Sodium.

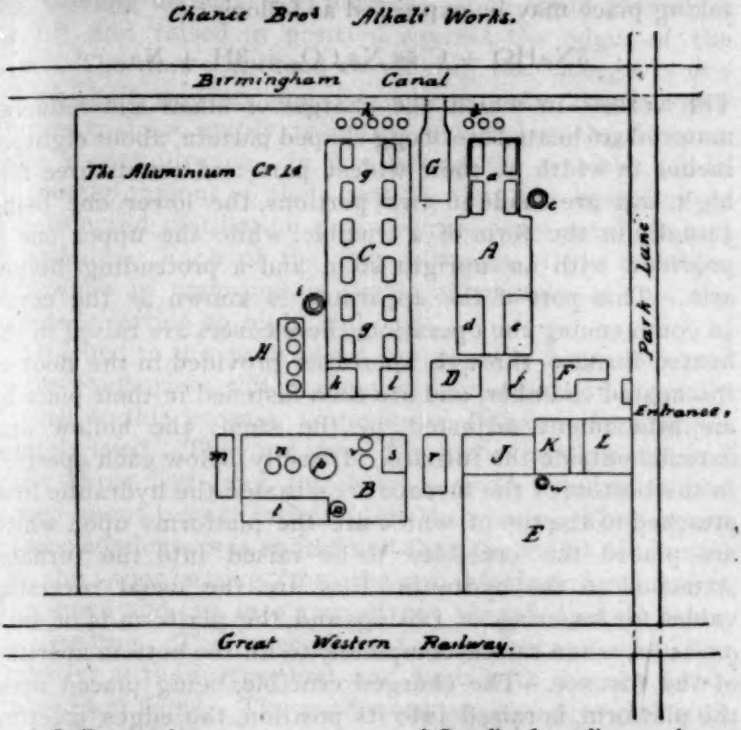
(2) Chlorine.
(3) Chloride.
(4) Aluminium.
(5) Foundry, rolling, wire mills, etc.

In each department an accurate account is kept of the production each day, the amount of material used, the different furnaces and apparatus in operation, etc. In this manner it has been found possible to ascertain each day exactly how the different processes are progressing, and what effect any modification has, either on cost, quantity, or quality of product. By this means a complicated chemical process is reduced to a series of very simple operations, so that whilst the processes are apparently complicated and difficult to carry out successfully, this is not the case now that the details connected with the manufacture have been perfected, and each operation carried on quite independently until the final materials are brought together for the production of the aluminium.

MANUFACTURE OF SODIUM.

The first improvement occurs in the manufacture of sodium by what is known as the "Castner Process." The successful working of this process marks an era in the production of sodium, as it not only has greatly cheapened the metal, but also has enabled the manufacture to be carried out upon a very large scale with little or no danger. Practically the process consists in heating fused caustic soda in contact with carbon whilst the former substance is in a perfectly liquid condition. By the process in vogue before the introduction of this method, it was always deemed necessary that special means should be taken to guard against actual fusion of the mixed charges, which, if it were to take place, would to a large extent allow the alkali and reducing material to separate. Thus having an infusible charge to heat, requiring the employment of a very high temperature for its decomposition, the iron vessels must be of small circumference to allow the penetration of the heat to the centre of the charge without actually melting the vessel in which the materials are heated. By the new process, owing to the

alkali being in a fused or perfectly liquid condition in contact directly with carbon, the necessity of this is avoided,



A. Sodium works.
B. Chlorine works.
C. Double chloride works.
D. Aluminium furnaces.
E. Rolling mills, etc.
F. Offices and laboratory.
G. Arm of canal.
H. Chlorine gasometers.
J. Wire mill.
K. Foundry.
L. Warehouse.
a. Sodium furnaces.
b. Gas producers.
c. Chimney, 150 feet high, 7 feet diameter inside.
d. Sodium casting and storage.
e. Engine and boiler rooms.
f. Supplies for sodium works.
g. Chloride furnaces.
h. Gas producers.
i. Chimney, 180 feet high, 10 feet diameter inside.
k. Mixing room for balls.
l. Purifying and storing chloride.
m. Storage vats for acid.
n. Chlorine stills.
p. Neutralizing well.
u. Oxidizing tower.
t. Settling tanks.
v. Lime vats.
s. Boilers.
r. Blowing engine.
w. Chimney.

and consequently, the reduction can be carried on in large vessels at a comparatively low temperature. The reaction taking place may be expressed as follows:

$$3NaHO + C = Na_2CO_3 + 3H + Na.$$

The vessels in which the charges of alkali and reducing material are heated are of egg-shaped pattern, about eighteen inches in width at their widest part and about three feet high, and are made in two portions, the lower one being actually in the form of a crucible, while the upper one is provided with an upright stem and a protruding hollow arm. This part of the apparatus is known as the cover. In commencing the operation, these covers are raised in the heated furnace through apertures provided in the floor of the heated chamber, and are then fastened in their place by an attachment adjusted to the stem; the hollow arm extends outside the furnace. Directly below each aperture in the bottom of the furnace are situated the hydraulic lifts, attached to the top of which are the platforms upon which are placed the crucibles to be raised into the furnace. Attached to the hydraulic lifts are the usual reversing valves for lowering or raising, and the platform is of such a size as, when raised, completely to fill the bottom aperture of the furnace. The charged crucible, being placed upon the platform, is raised into its position, the edges meeting those of the cover, forming an air-tight joint which prevents the escape of gas and vapor from the vessel during reduction, except by the hollow arm provided for this purpose. The natural expansion of the iron vessels is accommodated by the water pressure in the hydraulic lifts, so that the joint of the cover and crucible are not disturbed until it is intended to lower the lift for the purpose of removing the crucible.

The length of time required for the first operation of reduction and distillation is about two hours. At the end of this time the crucibles are lowered, taken from the platforms by a large pair of tongs on wheels, carried to a dumping pit, and thrown on their sides. The residue is cleaned out, and the hot pot, being again gripped by the tongs, is

taken back to the furnace. On its way, the charge of alkali and reducing material is thrown in. It is again placed on the lift and raised in position against the edges of the cover. The time consumed in making the change is one and one-half minute, and it requires only about seven minutes to draw, empty, recharge, and replace the five crucibles in each furnace. In this manner the crucibles retain the greater amount of their heat, so that the operation of reduction and distillation now requires only one hour and ten minutes. Each of the four furnaces, of five crucibles each, when in operation, is drawn alternately, so that the process is carried on night and day.

Attached to the protruding hollow arm from the cover are the condensers, which are of a peculiar pattern specially adapted to this process, being quite different from those formerly used. They are about five inches in diameter, and nearly three feet long, and have a small opening in the bottom about twenty inches from the nozzle. The bottom of these condensers is so inclined that the metal condensed from the vapor issuing from the crucible during reduction, flows down and out into a small pot placed directly below this opening. The uncondensed gases escape from the condenser at the further end, and burn with the characteristic sodium flame. The condensers are also provided with a small hinged door at the further end, by means of which the workmen from time to time may look in to observe how the distillation is progressing. Previous to drawing the crucibles from the furnace for the purpose of emptying and recharging, the small pots containing the distilled metal are removed, and empty ones substituted. Those removed each contain on an average about six pounds of metal, and are taken directly to the sodium casting shop, where it is melted and cast, either into large bars ready to be used for making aluminium, or in smaller sticks to be sold.

Special care is taken to keep the temperature of the furnaces at about 1,000° C., and the gas and air valves are carefully regulated, so as to maintain as even a temperature as possible. The covers remain in the furnace from Sunday

night to Saturday afternoon, and the crucibles are kept in use until they are worn out, when new ones are substituted without interrupting the general running of the furnace. A furnace in operation requires 250 pounds of caustic soda every one hour and ten minutes, and yields in the same time thirty pounds of sodium, and about 240 pounds of crude carbonate of soda. With the four furnaces at work 120 pounds of sodium can be made every seventy minutes or over a ton in the twenty-four hours. The residual carbonate, on treatment with lime in the usual manner, yields two-thirds of the original amount of caustic operated upon. The sodium, after being cast, is saturated with kerosene oil, and stored in large tanks holding several tons, placed in rooms specially designed for security against either fire or water.

CHLORINE MANUFACTURE.

This part of the works is connected with the adjacent works of Messrs. Chance Brothers, by a large gutta-percha pipe, by means of which, from time to time, hydrochloric acid is supplied direct into the large storage cisterns, from which it is used as desired for making the chlorine. For the preparation of the chlorine gas needed in making the chloride, the usual method is employed; that is, hydrochloric acid and manganese dioxide are heated together, when chlorine gas is evolved with effervescence, and is led away by earthenware and lead pipes to large lead-lined gasometers, where it is stored.

The materials for the generation of the chlorine are brought together in large tanks, or stills, built up out of great sandstone slabs, having rubber joints, and the heating is effected by the injection of steam. The evolution of gas, at first rapid, becomes gradually slower, and at last stops; the hydrochloric acid and manganese dioxide being converted into chlorine and manganous chloride. This last compound remains dissolved in the "spent still liquor" and is reconverted into manganese dioxide, to be used over again, by Weldon's manganese recovery process. Owing to the difficulty of keeping up a regular supply of chlorine

under a constant pressure directly from the stills, in order that the quantity passed into the sixty different retorts in which the double-chloride is made can be regulated and fed as desired, four large gasometers were erected. Each of these is capable of holding 1,000 cubic feet of gas, and is completely lined with lead, as are all the connecting mains, etc., this being the only available metal which withstands the corrosive action of chlorine. The gasometers are filled in turn from the stills, the chlorine consumed being taken direct from a gasometer under a regular pressure until it is exhausted, the valves being changed, the supply is taken from another holder, the empty one being refilled from the still.

MANUFACTURE OF THE DOUBLE CHLORIDE.

Twelve large regenerative gas furnaces are used for heating, and in each of these are fixed five horizontal fire-clay retorts about ten feet in length, into which the mixture for making the double chloride is placed. These furnaces have been built in two rows, six on a side, the clear passage-way down the centre of the building, which is about 250 feet long, being fifty feet in width. Above this central passage is the staging, carrying the large lead mains for the supply of the chlorine coming from the gasometers. Opposite each retort and attached to the main, are situated the regulating values, connected with lead and earthenware pipes, for the regulation and passage of the chlorine to each retort. The valves are of peculiar design, and have been so constructed that the chlorine is made to pass through a certain depth of liquid, which not only by opposing a certain pressure allows a known quantity of gas to pass in a given time, but also prevents any return from the retort into the main, should an increase of pressure be suddenly developed in the retorts.

The mixture with which the retorts are charged is made by grinding together hydrate of alumina, salt, and charcoal. This mixture is then moistened with water, which partially dissolves the salt, and thrown into a pug mill of the usual type for making drain pipes, excepting that the mass is

forced out into solid cylindrical lengths upon a platform alongside of which a workman is stationed with a large knife, by means of which the material is cut into lengths of about three inches each. These are then piled on top of the large furnaces to dry. In a few hours they have sufficiently hardened to allow of their being handled. They are then transferred to large wagons, and are ready to be used in charging the retorts.

The success of this process is in a great measure dependent:

(1) On the proportionate mixture of materials.

(2) On the temperature of the furnace.

(3) On the quantity of chlorine introduced in a given time.

(4) On the actual construction of the retorts.

I am, however, not at liberty to discuss the details of this part of the process, which have only a commercial interest. In carrying on the operation, the furnaces or retorts, when at the proper temperature, are charged by throwing in the balls until they are quite full, the fronts are then sealed up, and the charge allowed to remain undisturbed for about four hours, during which time the water of the alumina hydrate is completely expelled. At the end of this time the valves on the chlorine main are opened, and the gas is allowed to pass into the charged retorts. In the rear of each retort, and connected therewith by means of an earthenware pipe, are the condenser boxes, which are built in brick. These boxes are provided with openings or doors and also with earthenware pipes, connected with a small flue for carrying off the uncondensed vapors to the large chimney. At first the chlorine passed into each retort is all absorbed by the charge, and only carbonic oxide escapes into the open boxes, where it burns. After a certain time, however, dense fumes are evolved, and the boxes are then closed, while the connecting pipe between the box and the small flue serves to carry off the uncondensed vapors to the chimney.

The reaction which takes place is as follows:

$$Al_2O_3 + 2NaCl + 3C + 6Cl = 2AlCl_3NaCl + 3CO.$$

The chlorine is passed in for about seventy-two hours in varying quantity, the boxes at the back being opened from time to time by the workmen to ascertain the progress of the distillation. At the end of the time mentioned the chlorine valves are closed and the boxes at the back of the furnace are all thrown open. The crude double chloride, as distilled from the retorts, condenses in the connecting pipe and trickles down into the boxes, where it solidifies in large irregular masses. The yield from a bench of five retorts will average from 1,600 to 1,800 pounds, which is not far from the theoretical quantity. After the removal of the crude chloride from the condenser boxes, the retorts are opened at their charging end, and the residue, which consists of a small quantity of alumina, charcoal and salt is raked out and remixed in certain proportions with fresh material, to be used over again. The furnace is immediately re-charged and the same operations repeated, so that from each furnace upwards of 3,500 pounds of chloride are obtained weekly. With ten of the twelve furnaces always at work, the plant is easily capable of producing 30,000 pounds of chloride per week, or 1,500,000 pounds per annum.

Owing to the presence of iron, both in the materials used (viz., charcoal, alumina, etc.) and in the fire-clay composing the retorts, the distilled chloride always contains a varying proportion of this metal in the form of ferrous and ferric chlorides. When it is remembered that it requires ten pounds of this chloride to produce one pound of aluminium by reduction, it will be quite apparent how materially a very small percentage of iron in the chloride will influence the quality of the resulting metal. I may say that, exercising the utmost care as to the purity of the alumina and the charcoal used, and after having the retorts made of special fire-clay containing only a very small percentage of iron, it was found almost impossible to produce upon a large scale a chloride containing less than 0·3 per cent. of iron.

This crude double chloride, as it is now called at the works, is highly deliquescent, and varies in color from a light yellow to a dark red. The variation in color is not

so much due to the varying percentage of iron contained, as to the relative proportion of ferric or ferrous chlorides present, and although a sample may be either very dark or quite light, it may still contain only a small percentage of iron if it be present as ferric salt, or a very large percentage if it is in the ferrous condition. Even when exercising all possible precautions, the average analysis of the crude double chloride shows about 0·4 per cent. of iron. The metal subsequently made from this chloride, therefore, never contained much less than about five per cent. of iron, and as this quantity greatly injures the capacity of aluminium for drawing into wire, rolling, etc., the metal thus obtained required to be refined. This was successfully accomplished by Mr. Castner and his able assistant, Mr. Cullen, and for some time all the metal made was refined, the iron being lowered to about two per cent.

The process, however, was difficult to carry out, and required careful manipulation, but as it then seemed the only remedy for effectively removing the iron, it was adopted and carried on for some time quite successfully, until another invention of Mr. Castner rendered it totally unnecessary. This consisted in purifying the double chloride before reduction. I cannot now explain this process, but I am able to show some of the product. This purified chloride, or pure double chloride, is, as you see, quite white, and is far less deliquescent than the crude, so that it is quite reasonable to infer that this most undesirable property is greatly due to the former presence of iron chlorides. I have seen large quantities containing upwards of one and one-half per cent. of iron, or 150 pounds to 10,000 of the chloride, completely purified from iron in a few minutes, so that, whilst the substance before treatment was wholly unfit for the preparation of aluminium, owing to the presence of iron, the result was, like the sample exhibited, a mass containing only one pound of iron in 10,000, or 0·01 per cent. The process is extremely simple, and adds little or no appreciable cost to the final product. After treatment this pure chloride is melted in large iron pots and run into drums similar to those used for storing caustic soda. As

far as I am aware, it was generally believed to be an impossibility to remove the iron from anhydrous double chloride of aluminium and sodium, and few, if any, chemists have ever seen a pure white double chloride.

ALUMINIUM MANUFACTURE.

I now come to the final stage of the process, viz., the reduction of the pure double chloride by sodium. This is effected, not in a tube of Bohemian glass, as shown in Mr. Barlow's lecture in 1856, but in a large reverberatory furnace, having an inclined hearth about six feet square, the inclination being towards the front of the furnace, through which are several openings at different heights. The pure chloride is ground together with cryolite in about the proportions of two to one, and is then carried to a staging erected above the reducing furnace. The sodium, in large slabs or blocks, is run through a machine similar to an ordinary tobacco-cutting machine, where it is cut into small thin slices; it is then also transferred to the staging above the reducing furnace.

Both materials are now thrown into a large revolving drum, when they become thoroughly mixed. The drum being opened and partially turned, the contents drop out into a car on a tramway directly below. The furnace having been raised to the desired temperature, the dampers of the furnace are all closed to prevent the access of air, the heating gas also being shut off. The car is then moved out on the roof of the furnace until it stands directly over the centre of the hearth. The furnace roof is provided with large hoppers, and through these openings the charge is introduced as quickly as possible. The reaction takes place almost immediately, and the whole charge quickly liquefies. At the end of a certain time the heating gas is again introduced and the charge kept at a moderate temperature for about two hours. At the end of this period the furnace is tapped by driving a bar through the lower opening, which has previously been stopped with a fire-clay plug, and the liquid metal run out in a silver stream into moulds placed below the opening. When the metal has all

been drawn off, the slag is allowed to run out into small iron wagons and removed. The openings being again plugged up, the furnace is ready for another charge. From each charge, composed of about 1,200 pounds of pure chloride, 600 pounds of cryolite, and 350 pounds of sodium, about 115 to 120 pounds of aluminium is obtained.

The purity of the metal entirely depends upon the purity of the chloride used, and without exercising more than ordinary care the metal tests usually indicate a purity of metal above ninety-nine per cent. On the table is the metal run from a single charge, its weight is 116 pounds, and its composition, as shown by analysis, is 99·2 aluminium, 0·3 silicon and 0·5 iron. This I believe to be the largest and the purest mass of metal ever made in one operation.

The result of eight or nine charges are laid on one side, and then melted down in the furnace to make a uniform quality, the liquid metal, after a good stirring, being drawn off into moulds. These large ingots, weighing about sixty pounds each, are sent to the casting shop, there to be melted and cast into the ordinary pigs, or other shapes, as may be required for the making of tubes, sheets, or wire, or else used directly for making alloys of either copper or iron.

The following table shows approximately the quantity of each material used in the production of one ton of aluminium:

Metallic sodium,	6,300 pounds.
Double chloride,	22,400 "
Cryolite,	8,000 "
Coal,	8 tons.

To produce 6,300 pounds of sodium is required:

Caustic soda,	44,000 pounds.
Carbide made from pitch, 12,000 pounds, and iron turnings, 1,000 pounds,	7,000 "
Crucible castings,	2½ tons.
Coal,	75 "

For the production of 22,400 pounds of double chloride is required:

Common salt,	8,000 pounds.
Alumina hydrate,	11,000 "
Chlorine gas,	15,000 "
Coal,	180 tons.

For the production of 15,000 pounds of chlorine gas is required:

Hydrochloric acid,	180,000 pounds.
Limestone dust,	45,000 "
Lime,	30,000 "
Loss of manganese,	1,000 "

(These figures were rendered more evident by the aid of small blocks, each cut a given size so as to represent the relative weights of the different materials used to produce one unit of aluminium.)

It might seem, on looking over the above numbers, as if an extraordinary amount of waste occurred, and as if the production is far below that which ought to be obtained, but a study of the figures will show that this is not the case. I would wish to call attention to one item in particular, viz., fuel, it having been remarked that the consumption of coal must prevent cheap production. I think when it is remembered that coal, such as used at the works, cost only four shillings per ton, while the product is worth £2,240 per ton, the cost of coal is not an item of consequence in the cost of production. The total cost of the coal to produce one ton of metal being £50; the actual cost for fuel is less than sixpence for every pound of aluminium produced. The ratio of cost of fuel to value of product is indeed less than is the case in making either iron or steel. In concluding my remarks as to the method of manufacture and the process in general, I may add that I do not think it is too much to expect, in view of the rapid strides already made, that in the future, further improvements and modifications will enable aluminium to be produced and sold even at a lower price than appears at present possible.

PROPERTIES OF ALUMINIUM.

In its physical properties aluminium widely differs from all the other metals. Its color is a beautiful white, with a slight blue tint. The intensity of this color becomes more apparent when the metal has been worked, or when it contains silicon or iron. The surface may be made to take a very high polish, when the blue tint of the metal becomes

manifest, or it may be treated with caustic soda and then nitric acid, which will leave the metal quite white. The extensibility or malleability of aluminium is very high, ranking with gold and silver if the metal be of good quality. It may be beaten out into thin leaf quite as easily as either gold or silver, although it requires more careful annealing.

It is extremely ductile and may be easily drawn, especial care being required only in the annealing.

The excessive sonorousness of aluminium is best shown by example (large suspended bar being struck). Faraday has remarked, after experiments conducted in his laboratory, that the sound produced by an ingot of aluminium is not simple, and one may distinguish the two sounds by turning the vibrating ingot.

After being cast it has about the hardness of pure silver, but may be sensibly hardened by hammering.

Its tensile strength varies between twelve and fourteen tons to the inch (test sample which was shown having been broken at thirteen tons or 27,000 pounds), ordinary cast iron being about eight tons. Comparing the strength of aluminium in relation to its weight, it is equal to steel of thirty-eight tons tensile strength. The specific gravity of cast aluminium is 2·58, but after rolling or hammering this figure is increased to about 2·68.

The specific gravity of aluminium being one, copper is 3·6, nickel 3·5, silver 4, lead 4·8, gold 7·7.

The fusibility of aluminium has been variously stated as being between that of zinc and silver, or between 600 and 1,000° C.

As no reliable information has ever been made public on this subject, my friend, Professor Carnelley, undertook to determine it. I was aware from information gained at the works at Oldbury, that a small increase in the percentage of contained iron materially raised its point of fusion, and it has been undoubtedly due to this cause that such wide limits are given for the melting point. Under these circumstances two samples were forwarded for testing, of which No. 1, containing one-half per cent. of iron, had a melting

point of 700° C.; whereas No. 2, containing five per cent. of iron, does not melt at 700° and only softens somewhat above that temperature, but undergoes incipient fusion at 730°.

According to Faraday, aluminium ranks very high among metallic conductors of heat and electricity, and he found that it conducted heat better than either silver or copper. The specific heat is also very high, which accounts for length of time required for an ingot of the metal to either melt or get cold after being cast.

Chemically, its properties are well worthy of study.

Air, either wet or dry, has absolutely no effect on aluminium at the ordinary temperature, but this property is only possessed by a very pure quality of metal, and the pure metal in mass undergoes only slight oxidation even at the melting point of platinum.

Thin leaf, however, when heated in a current of oxygen, burns with a brilliant, bluish white light. (Experiment shown.) If the metal be pure, water has no effect on it whatever, even at a red-heat. Sulphur and its compounds also are without action on it, while, under the same circumstances, nearly all metals would be discolored with great rapidity. (Experiment shown using silver and aluminium under the same conditions.)

Dilute sulphuric acid and nitric acid, both diluted and concentrated, have no effect on it, although it may be dissolved in either hydrochloric acid or caustic alkali. Heated in an atmosphere of chlorine it burns with a vivid light, producing aluminium chloride. (Experiment shown.) In connection with the subject it may be of interest to state the true melting point of the double chloride of aluminium and sodium, which has always been given at 170° to 180° C., but which Mr. Baker, the chemist to the works, finds lies between 125° and 130° C.

USES OF ALUMINIUM.

Its uses, unalloyed, have heretofore been greatly restricted. This is, I believe, owing only to its former high price, for no metal possessing the properties of

aluminium could help coming into larger use if its cost were moderate. Much has been said as to the impossibility of soldering it being against its popular use, but I believe that this difficulty will now soon be overcome. The following are a few of the purposes to which it is at present put: telescope tubes, marine glasses, eye-glasses and sextants, especially on account of its lightness. Fine wire for the making of lace, embroidery, etc. Leaf in the place of silver leaf, sabre sheaths, sword handles, etc., statuettes and works of art, jewelry and delicate physical apparatus, culinary utensils, harness fittings, metallic parts of soldiers' uniforms, dental purposes, surgical instruments, reflectors (as it is not tarnished by the products of combustion), photographic apparatus, aëronautical and engineering purposes, and especially for the making of alloys.

ALLOYS OF ALUMINIUM.

The most important alloys of aluminium are those made with copper. These alloys were first prepared by Dr. Percy, in England, and now give promise of being largely used. The alloy produced by the addition of ten per cent. of aluminium to copper, the maximum amount that can be used to produce a satisfactory alloy, is known as aluminium bronze. Bronzes, however, are made which contain smaller amounts of aluminium, possessing in a degree the valuable properties of the ten per cent. bronze. According to the percentage of aluminium up to ten per cent., the color varies from red gold to pale yellow. The ten per cent. alloy takes a fine polish, and has the color of jewellers' gold. The five per cent. alloy is not quite so hard, the color being very similar to that of pure gold. I am indebted to Prof. Roberts Austen for a splendid specimen of crystallized gold, as also for a mould in which the gold at the mint is usually cast, and in this I have had prepared ingots of the ten and five per cent. alloy, so that a comparison may be made of the color of these with a gold ingot cast in the same mould, for the loan of which I have to thank Messrs. Johnson, Matthey & Co. (specimens shown).

I have also ingots of the same size, of pure aluminium,

from which an idea of the relative weights of gold and aluminium may be obtained.

To arrive at perfection in the making of these alloys, not only is it required that the aluminium used should be of good quality, but also that the copper must be of the very best obtainable. For this purpose only the best brands of Lake Superior copper should be used. Inferior brands of copper or any impurities in the alloy give poor results. The alloys all possess a good color, polish well, keep their color far better than all other copper alloys, are extremely malleable and ductile, can be wrought either hot or cold, easily engraved, the higher grades have an elasticity exceeding steel, are easily cast into complicated forms, do not lose in remelting, and are possessed of great strength, dependent, of course, on the purity and percentage of contained aluminium. The ten per cent. alloy, when cast, has a tensile strength of between 70,000 and 80,000 pounds per square inch, but when hammered or wrought, the test exceeds 100,000 pounds. (A sample shown broke at 105,000 pounds.)

An attempt to enumerate either the present uses or the possible future commercial value of these alloys is beyond my present purpose. I may, however, remark that they are not only adapted to take the place of bronze, brass and steel, but they also so far surpass all of those metals, both physically and chemically, as to make their extended use assured. (Sheets, rods, tubes, wire and ingots shown.)

But even a more important use of aluminium seems to be its employment in the iron industry, of which it promises shortly to become a valuable factor, owing to certain effects which it produces when present, even in the most minute proportions. Experiments are now being carried on at numerous iron and steel works, in England, on the Continent and in America. The results, so far attained, are greatly at variance, for whilst in the majority of cases the improvements made have encouraged the continuance of the trials, in others the result has not been satisfactory. On this point I would wish to say to those who may contemplate making use of aluminium in this direction, that it

would be advisable, before making their experiments, to ascertain whether the aluminium alloy they may purchase actually contains any aluminium at all, for some of the so-called aluminium alloys contain little or no aluminium, and this would doubtless account for the negative results obtained. Again, others contain such varying proportions of carbon, silicon and other impurities, as to render their use highly objectionable.

It seems to be a prevailing idea with some persons, that because aluminium is so light compared with iron, it cannot be directly alloyed, and furthermore, that for the same reason, alloys made by the direct melting together of the two metals would not be equal to an alloy where both metals are reduced together. Now, of course, this is not the case, and the statement has been put forward by those who were able to make the alloys in one way only.

Aluminium added to molten iron and steel lowers their melting points, consequently increases the fluidity of the metal, and causes it to run easily into moulds and set there without entrapping air and other gases, which serve to form blow-holes and similar imperfections. It is already used by a large number of steel founders, and seems to render the production of sound steel castings more certain and easy than is otherwise possible.

One of the most remarkable applications of this property which aluminium possesses of lowering the melting-point of iron, has been made use of by Mr. Nordenfelt in the production of castings of wrought iron.

Aluminium forms alloys with most other metals, and although each possesses peculiar properties, which in the future may be utilized, at present they are but little used.

In conclusion, I beg to call your attention to the wood models on the table, one being representative of aluminium, the other aluminium bronze. The originals of these models are now in the Paris Exposition, each weighing 1,000 pounds. With regard to aluminium bronze, I cannot speak positively, but the block of pure aluminium is undoubtedly the largest casting ever made in this most wonderful metal. I have to thank the Directors of the Aluminium Company,

and especially Mr. Castner, for furnishing me with the interesting series of specimens of raw and manufactured metal for illustrating my discourse.

NOTE.—The exhibit consisted of five to six hundred-weight of aluminium (ninety-eight to ninety-nine per cent.) in various sizes of pigs, ingots, sheet, wire, foil, tubes and rods. Two large blocks, together weighing 116 pounds and testing 99·2 per cent. aluminium, as run direct from the furnace in one charge. Four hundred-weight of aluminium bronzes in pigs, ingots, wire, tubes, sheet and rods. Aluminium iron and steel, ten and twenty per cent. aluminium, one hundred-weight of each in pigs. Sodium in cast bars. Double chloride of aluminium and sodium (crude and purified).

ON THE DILATATION OF COMPRESSED LIQUIDS, PARTICULARLY WATER.*

BY E. H. AMAGAT.

Translated by Chief Engineer ISHERWOOD, U.S.N.

I have investigated the compressibility and the dilatation of the following liquids between zero and 50°, under pressures varying from one atmosphere to 3,000 atmospheres, namely, water, ordinary ether, the methylic, ethylic, propylic and allylic alcohols, acetone, the chloride, bromide and iodide of ethyl, the sulphide of carbon and the chloride of phosphorus.

I shall not be able to give the absolute coefficients of compressibility until I have finished the very difficult work relative to the compressibility of the piezometers, but the coefficients of dilatation under constant pressure can be calculated now, and the following is a summary of the results I have obtained:

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* *Comptes Rendus*, December 5, 1887, p. 1120.

Putting water, which is an exception, on one side, the coefficient of dilatation of the other liquids diminishes when the pressure upon them increases, the diminution becoming less and less marked as the pressure becomes greater and greater, but under even 3,000 atmospheres it is still very sensible.

Under the atmospheric pressure the coefficient, as is well known, augments with the temperature; this variation diminishes when the pressure increases, until it falls within the limits of error for the experimental conditions employed; for example, in the case of ether under the pressure of 1,000 atmospheres, I have found for mean coefficients between zero and the temperatures of 10°, 20°, 30°, 40° and 50° the following numbers: 0·000891, 0·000890, 0·000905, 0·000897, 0·000909. The other liquids gave analogous results.

My principal object, above all others, was to ascertain the effects of the great pressures. A method was employed up to about 1,200 or 1,500 atmospheres totally different from the apparatus arranged for the highest pressures, and capable of sustaining a pressure which could not be produced in it; the temperature could be raised a number of hundreds of degrees, and, consequently, the critical points of several liquids could be reached.

Atmospheres.	1.	500.	1,000.	1,500.	2,000.	2,500.	3,000.
Ether, ...	0·001700	0·001118	0·000909	0·000772	0·000700	0·000631	0·000558
Sulphide of carbon, . . .	0·001212	0·000940	0·000828	0·000735	0·000666	0·000630	0·000581
Alcohol, ...	0·001109	0·000866	0·000730	0·000673	0·000613	0·000556	0·000524
Water.							
From 0° to 10°, ...	0·000012	0·000156	0·000250	0·000315	0·000352	0·000338	0·000383
From 0° to 30°, ...	0·000138	0·000229	0·000302	0·000340	0·000382	0·000420	0·000415
From 0° to 50°, ...	0·000236	0·000295	0·000347	0·000383	0·000408	0·000428	0·000413

The foregoing table contains some of the results determined. It gives the mean coefficients of ether and of sulphide of carbon between zero and 50° and the coefficient of ordinary alcohol between zero and 40° under the different

pressures, increasing by 500 atmospheres, up to 3,000 atmospheres. The coefficients of water under the same pressures are therein given from zero to 10°, to 30° and to 50°, in order to show their variations with the temperature.

We see that at 3,000 atmospheres the coefficient of the ether was reduced to the third of the value it had at the atmospheric pressure.

Comparing the ether and the sulphide of carbon, we see that the ether, which at the pressure of one atmosphere is a great deal more dilatable than the sulphide of carbon, has the same coefficient as the latter at the pressure of 2,500 atmospheres; but at the pressure of 3,000 atmospheres the coefficient of the sulphide of carbon is the greatest, this last coefficient having been lessened about one-half, while that of the ether has been lessened two-thirds.

The case of water is particularly interesting, because we therein see the gradual effacing of the perturbations of the ordinary laws resulting from the fact of the maximum of density.

At first, the coefficient of the water increases very rapidly with the pressure; then, this increase diminishes and disappears towards the pressure of 2,500 atmospheres; we might suppose that under very great pressures, the coefficient would continue to diminish, like that which takes place for the other liquids from the atmospheric pressure.

We will remark, finally, that the increase of the coefficient with the temperature varies considerably under the feeble pressures, diminishing gradually as the pressure rises; at the pressure of 500 atmospheres, the mean coefficient between zero and 50° is still double of that between zero and 10°, but at the pressure of 3,000 atmospheres this increase with the temperature, though distinctly marked, is extremely reduced. At this pressure the water between the experimental limits of temperature, conforms to the ordinary laws of dilatation of the other liquids.

Note by Translator.—In the foregoing article, the temperatures are given for the Centigrade scale. Zero, 10°, 30°, 40°

and 50° on it are, respectively, 32,° 50°, 86°, 104° and 122° on the Fahrenheit scale.

The mean coefficients of dilatation of the different liquids are the mean increase of unit of their volume at the Centigrade zero, in fractions of this unit, due to the experimental increase of temperature above zero, per atmosphere of pressure under the experimental number of atmospheres to which the liquids were subjected.

COMPRESSIBILITY OF THE GASES OXYGEN, HYDROGEN, NITROGEN AND AIR, UP TO THE PRESSURE OF 3,000 ATMOSPHERES.*

By E. H. Amagat.

Translated by Chief Engineer Isherwood, U.S.N.

The experiments on these gases were made according to the method I followed in my previous investigations of the compressibility of liquids within the same limits of pressure; but, in the present case, the difficulty was much greater, owing to the smallness of the volume of the gases when strongly compressed. Nevertheless, after numerous trials, I obtained perfectly regular and concordant results by employing, for the gauging of the platinum wire tubes, the same process of reading by electrical contacts which served afterwards to estimate in the same tubes the successive volumes of the compressed gases. In this manner I obtained for the same gas, with different tubes, graphic curves, which almost absolutely coincided with each other.

My results, given further on, and they are solely the apparent results, differ notably numerically from those obtained by Natterer. The differences within the limits common to our researches are very irregularly distributed, and amount to several hundreds of atmospheres. My experiments for the same reduction of the volume of the

* *Comptes Rendus*, September 17, 1888, p. 522.

gas, give in general much greater pressures than his, but the differences can easily be accounted for by the probable and even inevitable causes of error in the method followed by him.

The following results relate solely to great pressures; the pressures below 1,000 atmospheres will be investigated in part by means of an apparatus permitting the use of temperatures vastly higher than I have been able to command with the apparatus imposed by the very great pressures, and with which I have been able to operate between only 0° C. and 50° C.

The following table gives for the pressures, in the first column, the volumes of the gaseous mass at 15° Centigrade relatively to its volume as unity at the same temperature and under the pressure of one atmosphere:

Pressures in Atmospheres.	Air.	Nitrogen.	Oxygen.	Hydrogen.
750	0·002200	0·002262	. . .	. . .
1,000	0·001974	0·002032	0·001735	0·001688
1 500	0·001709	0·001763	0·001492	0·001344
2,000	0·001566	0·001613	0·001373	0·001161
2,500	0·001469	0·001515	0·001294	0·001047
3,000	0·001401	0·001446	0·001235	0·000964

The comparison of the compressibility of strongly compressed gases with each other, and with that of the liquids, is interesting, and to facilitate it I have calculated for differences of 500 atmospheres of pressure the coefficients of compressibility of the gases, as habitually defined for liquids. In the following table are the results obtained:

Limits of Pressure in Atmospheres.	Air.	Nitrogen.	Oxygen.	Hydrogen.
Between 750 and 1,000, . . .	0·000411	0·000407	. . .	. . .
Between 1,000 and 1,500, . . .	0·000268	0·000265	0·000258	0·000408
Between 1,500 and 2,000, . . .	0·000187	0·000170	0·000160	0·000272
Between 2,000 and 2,500, . . .	0·000123	0·000122	0·000115	0·000197
Between 2,500 and 3,000, . . .	0·000093	0·000091	0·000091	0·000158

We see that, under very great pressures, the gases oxygen, nitrogen and air, have nearly the same compres-

sibility; and that it is of the order of magnitude of the compressibility of the liquids; at 3,000 atmospheres it is sensibly equal to that of alcohol under normal pressure.

The compressibility of hydrogen is very much greater—nearly double—and at 3,000 atmospheres it is almost equal to that of ether under normal pressure.

There may be easily foreseen that these compressibilities should, as in the case of the liquids, increase with the temperature, which is shown, as regards hydrogen, by the following table:

Limits of Pressure in Atmospheres.	Coefficients.		
	At Zero.	At 15°·4.	At 47°·3.
Between 1,000 and 1,500,	0·000	0·000408	0·000416
Between 1,500 and 2,000,	0·000263	0·000272	0·000280
Between 2,000 and 2,500,	0·000196	0·000197	0·000208
Between 2,500 and 3,000,	0·000156	0·000158	0·000158

The apparent densities are easily deduced from the first table; and admitting, provisionally, for the compressibility of glass the number generally adopted, we obtain the following results for the pressure of 3,000 atmospheres:

Densities of the Gases under the Pressure of 3,000 Atmospheres, relatively to Water.

	Apparent.	*Real.*
Oxygen,	1·0972	1·1054
Air,	0·8752	0·8817
Nitrogen,	0·8231	0·8293
Hydrogen,	0·0880	0·8887

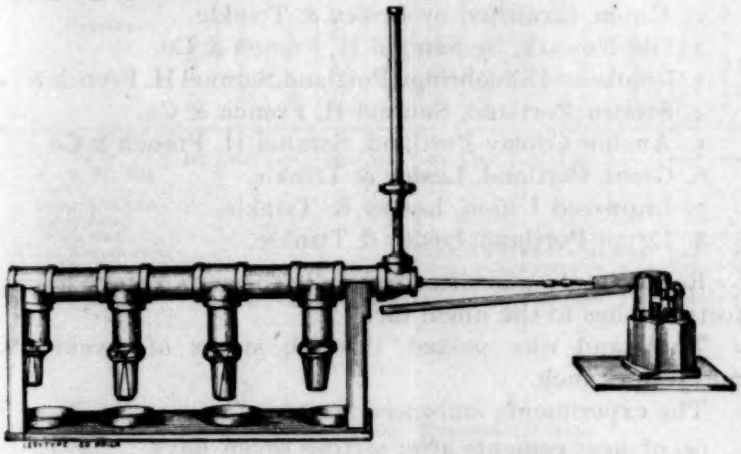
The curves obtained by laying off the pressures as abscissas on an axis, and the products $p\,v$ as corresponding ordinates perpendicular to the axis, are nearly straight lines, but they all have a slight concavity towards the axis. I shall return to this important point as regards the limited volumes after I shall have determined the variation of the volume of the envelopes.

RESULTS OF EXPERIMENTS MADE TO DETERMINE THE PERMEABILITY OF CEMENTS AND CEMENT MORTARS.

By G. W. HYDE AND W. J. SMITH, University of Pennsylvania.

Condensed by L. M. HAUPT.

The apparatus was designed to fulfil the requirements of simplicity, strength, tightness, accuracy, and facility for changing specimens.



It was found to be well adapted to the purpose and consisted of a cylinder composed of wrought-iron three-inch pipes screwed into four cast-iron tees. The far end was closed by a cap, the near end by a tie bushed down to admit the one-fourth-inch feed pipe, on end, and the gauge on top. The specimens to be tested were placed in short six-inch cylinders, three-inch diameter, having a thread cut on the upper end and a perforated cap on the bottom. The hole in the cap was one and one-half inches in diameter. Rubber washers were placed between the caps and samples to be tested, to prevent leakage at the joints. These cylinders containing the specimens were screwed tightly into the tees, and below them

glass beakers were attached by elastic bands to catch the water passing through the cements and mortars.

The water used was first filtered to prevent the choking of the pores by sediment. The pressure was applied by a hand force-pump and maintained throughout the series at 75, 100 and 200 pounds respectively. Four specimens were tested simultaneously.

The accompanying cut will illustrate the simplicity of the apparatus as assembled.

THE SPECIMENS.

Experiments were made on the following brands:

1. Unión, furnished by Lesley & Trinkle.
2. Old Newark, by Samuel H. French & Co.
3. Brooks and Shoebridge Portland, Samuel H. French & Co
4. Stettin Portland, Samuel H. French & Co.
5. Anchor Coplay Portland, Samuel H. French & Co.
6. Giant Portland, Lesley & Trinkle.
7. Improved Union, Lesley & Trinkle.
8. Egypt Portland, Lesley & Trinkle.

Each sample was sifted carefully through a sieve having forty meshes to the lineal inch.

The sand was passed through sieves of twenty-five meshes per inch.

The experiments embraced six series:

(*a*) of neat cements after setting seven days.

(*b*) of neat cements after twenty-eight days.

(*c*) of cement mortars, composed of equal parts of cement and sand after seven days.

(*d*) same after twenty-eight days.

(*e*) of cement mortar composed of one part of the former to two of the latter, seven days.

(*f*) same after twenty-eight days.

The specimens were carefully manipulated with just sufficient water to form a thin film when rammed in the mould so as to fill the cylinder to a height of three inches. The samples were allowed to drain for one day, after removing from the water in which they had set, before using.

The following tables give the numerical results of the experiments, showing the amount of percolation in ounces and quarts at the end of each hour under the varying pressures for seven and twenty-eight days, cements and mortars. Where no figures are given, there was no measurable percolation.

TABLE I.—Neat Cements. Seven Days.

No. of Specimen.	Variety.	Pressure, 75 Pounds per Sq. In.				Pressure, 100 Pounds per Sq. In.				Pressure, 200 Pounds per Sq. In.			
		First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
4	B. & S. Eng. Port.,												
24	Improved Union,												
15	Egypt Port.,												
20	Stettin Port.,						0·028	0·032	0·020	0·059	0·195	0·135	0·129
54	Old Newark Port.						0·091	0·227	0·106	0·424	0·525	0·498	0·482
22	Union,	0·044	0·143	0·139	0·108	0·094	0·224	0·169	0·162	0·261	0·361	0·358	0·326
11	Anchor (Coplay),	0·203	0·219	0·216	0·212	0·298	0·306	0·299	0·301	0·426	0·442	0·436	0·434
3	Giant Port.,	0·263	0·299	0·326	0·296	0·233	0·173	0·184	0·197	0·562	0·843	1·224	0·875

TABLE II.—Neat Cements. Twenty-eight Days.

No. of Specimen.	Variety.	Pressure, 75 Pounds per Sq. In.				Pressure, 100 Pounds per Sq. In.				Pressure, 200 Pounds per Sq. In.			
		First Hour	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
7	B. & S. Eng. Port.,												
23	Improved Union,												
14	Egypt Port.,												
41	Stettin Port.,												
6	Old Newark Port.												
21	Union,												
2	Giant Port.,												
10	Anchor (Coplay),	0·101	0·126	0·103	0·110	0·138	0·186	0·183	0·169	0·446	0·525	0·583	0·518

TABLE III.—Mortars. Seven Days.

Variety.	Ratio Cement to Sand.	Pressure, 75 Pounds per Square Inch.				Pressure, 100 Pounds per Square Inch.				Pressure, 200 Pounds per Square Inch.			
		First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ozs.	*ozs.*	*ozs*	*ozs.*	*ozs.*	*ozs*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*
9. Anchor (Coplay),	1 : 1	4·062	5·155	5·533	4·917	5·926	8·493	8·519	7·646	21·239	21·223	19·522	20·694
49. Stettin Port.,	1 : 2	6·819	6·965	6·9 1	6·8,5	10·693	10·916	10·894	10·834	31·342	37·607	34·229	34·392
42. Improved Union,	1 : 1	10·996	11·495	11·481	11·301	17·279	17·523	17·482	17·451	37·699	38 635	38·071	38·468
18. Union,	1 : 1	35·753	42·517	43·448	40·573	53·833	59·909	54·112	55·951	77·374	109·187	108·941	118·500
17. B. & S. Eng. Port.,	1 : 2	50·147	53·254	51·930	51·777	76·004	77·839	77·122	76·988	155·143	150·743	155·583	155·823
35. Giant Port.,	1 : 2	83·056	84·624	84·079	83·919	108·130	109·344	108·912	108 795	137·905	142·606	140·570	140·362
32. Old Newark Port.,	1 : 2	100·294	102·370	102·611	101·758	163·684	166·112	165·722	164·172	. . .	. . .	. . .	. .
13. Egypt Port.,	1 : 2	138·709	139·183	139·845	139·245	163·847	173·357	172·763	171·999	315·355	362·889	317·635	331·426

TABLE IV.—Mortars. Twenty-eight Days.

Variety.	Ratio Cement to Sand.	Pressure, 75 Pounds per Square Inch.				Pressure, 150 Pounds per Square Inch.				Pressure, 200 Pounds per Square Inch.			
		First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ccs.	*ccs.*	*ccs.*	*ccs.*	*ccs.*	*ccs.*	*ccs.*	*ccs.*	*ccs.*	*ccs.*	*ccs.*	*ccs.*
8. Anchor (Coplay),	1 : 1	1·188	0·978	1·061	1·075	1·706	1·829	1·882	1·805	4·308	4·827	4·743	4·626
16. Improved Union,	1 : 1	2·043	1·922	1·536	1·833	2·382	1·897	2·548	2·275	9·554	9·627	10·667	9·949
19. Union,	1 : 1	5·939	5·685	5·108	5·577	7·621	8·658	8·089	8·122	15·183	14·378	14·378	14·633
45. Stettin,	1 : 2	6·275	6·438	6·349	6·354	9·368	10·319	9·883	9·856	21·514	21·940	21·303	21·652
33. Egypt Port.,	1 : 2	13·214	15·061	14·066	14·113	27·291	28·259	27·814	27·781	52·149	52·711	50·867	51·909
5. Giant Port.,	1 : 2	22·314	23·916	24·015	23·415	35·809	47·746	52·187	45·214	99·290	109·978	99·833	103·033
12. B. & S. Eng. Port.,	1 : 2	35·699	36·055	35·436	35·730	43·744	45·316	44·154	44·404	65·069	65·718	65·342	65·393
39. Old Newark Port.,	1 : 2	109·697	112·831	111·354	111·294	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

TABLE V.—Neat Cements. Seven Days.

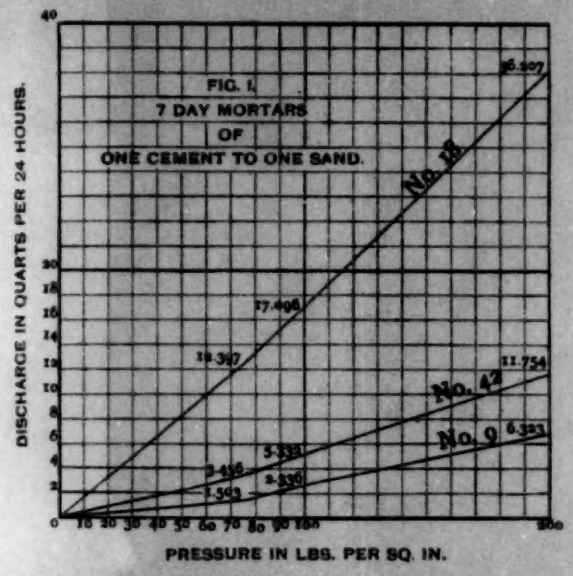
Variety.	Pressure, 75 Pounds Per Sq. In.		Pressure, 100 Pounds Per Sq. In.		Pressure, 200 Pounds Per Sq. In.	
	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.
4. B. & S. Eng. Port.,	. . .	. . .	. . .	. . .	. . .	. .
24. Improved Union,	. . .	. . .	. . .	. . .	. . .	. . .
15. Egypt Port.,	. . .	. . .	. . .	. . .	. . .	. . .
20. Stettin Port.,	. . .	. . .	0·008	0·006	0·055	0·040
54. Old Newark Port.,	. . .	. . .	0·045	0·032	0·205	0·143
22. Union,	0·046	0·033	0·069	0·050	0·134	0·096
11. Anchor (Coplay),	0·090	0·065	0·128	0·092	0·184	0·132
3. Giant Port.,	0·126	0·091	0·084	0·060	0·371	0·267

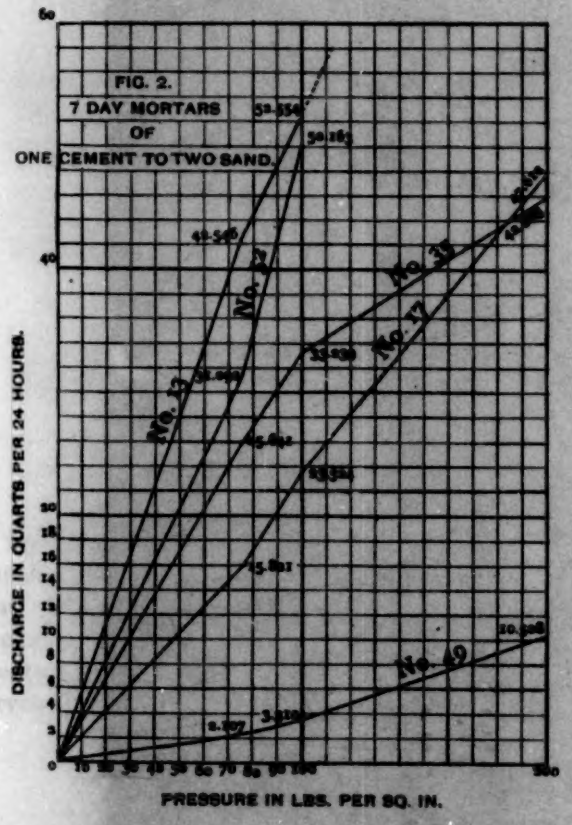
TABLE VI.—Neat Cements. Twenty-eight Days.

Variety.	Pressure, 75 Pounds Per Sq. In.		Pressure, 100 Pounds Per Sq. In.		Pressure, 200 Pounds Per Sq. In.	
	Ounces Per Surface of 1 Sq. In Per Hour.	Quarts Per Surface of 1 Sq. In. Per 24 Hours.	Ounces Per Surface of 1 Sq. In. Per Hour.	Quarts Per Surface of 1 Sq. In. Per 24 Hours.	Ounces Per Surface of 1 Sq. In. Per Hour.	Quarts Per Surface of 1 Sq. In. Per 24 Hours.
7. B. & S. Eng. Port.,	. . .	. . .	. . .	. . .	. . .	. . .
23. Improved Union,	. . .	. . .	. . .	. . .	. . .	. . .
14. Egypt Port.,	. . .	. . .	. . .	. . .	. . .	. . .
41. Stettin Port.,	. . .	. . .	. . .	. . .	. . .	. . .
6. Old Newark Port.,	. . .	. . .	. . .	. . .	. . .	. . .
21. Union,	. . .	. . .	. . .	. . .	. . .	. . .
2. Giant Port.,	. . .	. . .	. . .	. . .	. . .	. . .
10. Anchor (Coplay),	0·047	0·034	0·072	0·052	0·320	0·152

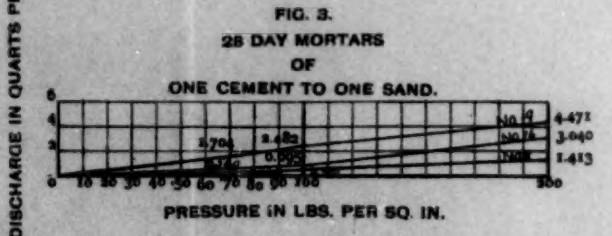
TABLE VII.—Mortars. Seven Days.

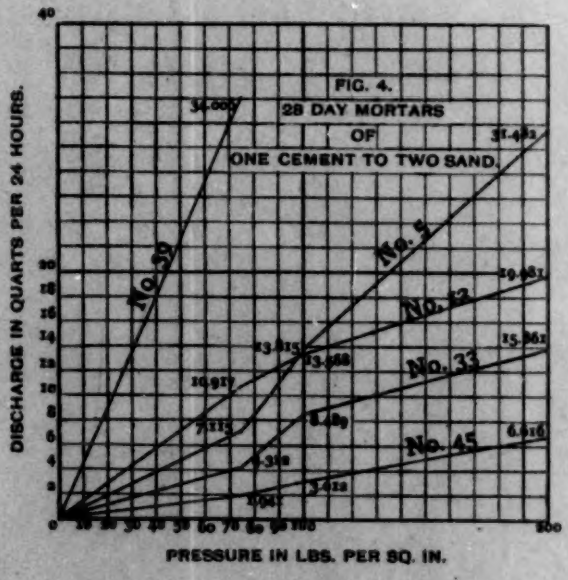
Variety.	Ratio Cement to Sand.	Pressure, 75 Pounds Per Sq. In.		Pressure, 100 Pounds Per Sq. In.		Pressure, 200 Pounds Per Sq. In.	
		Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.
9. Anchor (Coplay),	1 : 1	2·087	1·503	3·245	2·336	8·783	6·323
49. Stettin Port.,	1 : 2	2·926	2·107	4·598	3·310	14·596	10·508
42. Improved Union,	1 : 1	4·800	3·456	7·406	5·332	16·326	11·754
18. Union,	1 : 1	17·219	12·397	23·746	17·096	50·292	36·207
17. B. & S. Eng. Port.,	1 : 2	21·975	15·821	32·675	23·524	66·133	47·612
35. Giant Port.,	1 : 2	35·616	25·641	46·169	33·239	59·571	42·888
52. Old Newark Port.,	1 : 2	43·187	31·092	69·676	50·163	. . .	. . .
13. Egypt Port.,	1 : 2	59·097	42·546	72·998	52·554	140·661	101·268





	7 DAYS.	28 DAYS.
EGYPT PORT,	No. 13	33
OLD NEWARK PORT,	No 52	39
GIANT PORT,	No. 35	5
B. AND S. ENG. PORT,	No. 17	12
UNION,	No. 18	19
IMPROVED UNION,	No. 42	16
STETIN PORT,	No. 49	45
ANCHOR COPLEY,	No. 9	8





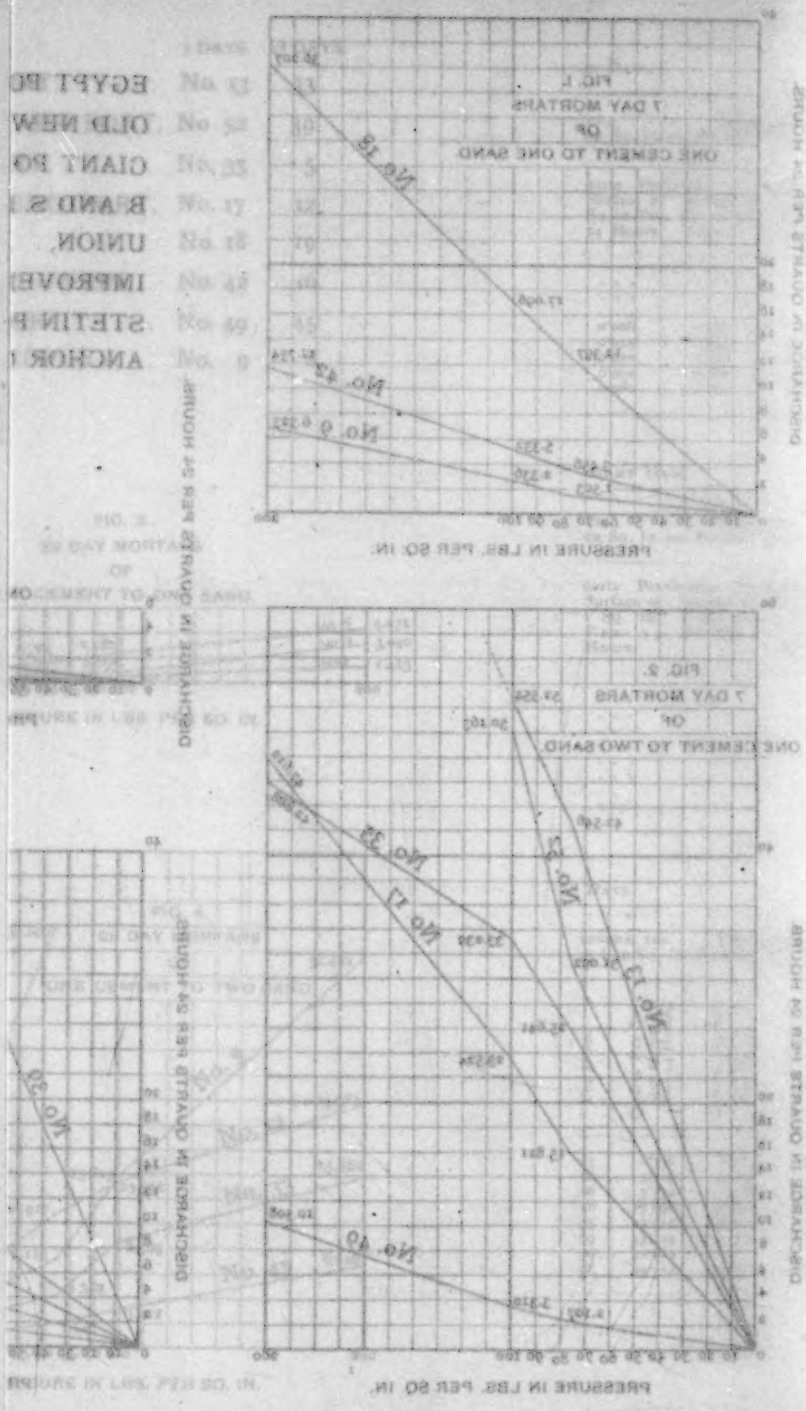


FIG. 1.
7 DAY MORTARS
OF
ONE CEMENT TO ONE SAND
No. 18
No. 12
No. 6
DISCHARGE IN GRAINS PER 24 HOUR
PRESSURE IN LBS. PER SQ. IN.
FIG. 2.
7 DAY MORTARS
OF
ONE CEMENT TO TWO SAND
No. 33
No. 17
No. 10
No. 25
DISCHARGE IN GRAINS PER 24 HOUR
PRESSURE IN LBS. PER SQ. IN.

TABLE VIII.—MORTARS. TWENTY-EIGHT DAYS.

VARIETY.	Ratio Cement to Sand.	PRESSURE, 75 POUNDS PER SQ. IN.		PRESSURE, 100 POUNDS PER SQ. IN.		PRESSURE, 200 POUNDS PER SQ. IN.	
		Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.
8. Anchor (Coplay), . .	1 : 1	0·456	0·328	0·766	0·551	1·963	1·413
16. Improved Union, . .	1 : 1	0·778	0·560	0·966	0·695	4·222	3·040
19. Union, ...	1 : 1	2·367	1·704	3·447	2·482	6·210	4·471
45. Stettin, ...	1 : 2	2·696	1·941	4·183	3·012	9·189	6·616
33. Egypt Port., ...	1 : 2	5·990	4·312	11·791	8·489	22·031	15·861
5. Giant Port., ...	1 : 2	9·938	7·155	19·189	13·815	43·728	31·482
12. B. & S. Eng. Port., .	1 : 2	15·164	10·917	18·846	13·568	27·754	19·981
39. Old Newark, ...	1 : 2	47·235	34·006	. . .	. . .	. .	. . .

ANALYSIS OF CEMENTS BY OLIVER HOUGH, B S., P.C.

		No. 2.	No. 3.	No. 4.	No. 6.	No. 5.	No. 7.	No. 8.*
Portion Soluble in HCl.	Silica, ...	23·92	16·88	21·14	20·99	10·18	24·44	16·22
	Alumina, ...	8·52	6·92	1·02	4·12	4·55	4·69	. . .
	Ferric oxide, ...	3·20	3·82	2·01	5·18	2·41	3·80	. . .
	Phosphoric acid, ...	1·82	1·08	. . .	1·17	1·33	0·50	. . .
	Lime, ...	45·07	58·40	66·04	60·75	59·91†	52·39	55·74
	Magnesia, ...	7·86	2·06	0·47	0·41	0·60	3·47	. . .
	Alkalies, ...	1·61	1·03	1·78	1·79	1·61	2·03	. . .
Insoluble Portion.	Calcium Sulphate, ...	3·21	4·32	3·73	5·02	2·01	3·24	2·57
	Silica, ...	11·33	4·99	4·36	1·45	13·39	5·87	7·35
	Alumina and ferric oxide, ...	2·59	0·60	trace	. . .	3·70	trace	1·05
	Oxide of manganese, ...		trace	. . .	. . .		trace	
	Magnesia, ...	0·86	0·36	. . .	. . .	0·31	. . .	. . .
	Total, ...	99·99	100·46	100·55	100·88	100·00	99·73	
	Total silica, ...	25·25	21·87	25·50	22·44	23·57	29·61	23·57
	Total alumina and ferric oxide, . .	14·31	11·34	3·03	9·30	10·66	8·49	. . .
	Total magnesia, ...	8·72	2·42	0·47	0·41	0·91	3·47	. . .

* Uncompleted.

† By difference.

The last four tables were computed from the results as stated in the first four, on the assumption that the percolation varies directly as the diameter and inversely as the thickness. They are reduced to the basis of quarts in twenty-four hours for greater convenience in plotting the curves.

These results show that all cements are not permeable to water, at least for thicknesses of not less than three inches, while the mortars are all permeable; the amount increases with the pressure and decreases with age of specimen, but not in a direct ratio.

Large surfaces, however, are very apt to contain cracks and flaws which greatly increase the permeability. Magnesia is an undesirable constituent, as it causes expansion and ultimate crumbling or flaking. Sulphur will destroy stone or concrete. It is more serious, as it is more intimately mixed. There are colors that contain so much sulphur as to destroy concrete.* The chemical compositions of the cements submitted are given in the above table.

The diagram herewith will give a more comprehensive view of the action of these specimens under pressure. No results are plotted for the non-permeable cements.

For the purpose of comparison it may be well to add that the Board of Experts on the Washington Aqueduct Tunnel in investigating this subject, found that "a good, fair specimen of brick, * * under a pressure of water amounting to eighty pounds per square inch, for one hour, passed 23·4 cubic inches of water." During the second hour it was 21·3 cubic inches. "This is equivalent to 1·75 gallons per square foot of surface per hour, or for the whole surface of the tunnel 27,342,000 gallons per day of twenty-four hours." "Blocks of cement mortar were prepared in the proportion of one part of cement to two of sand," and after setting in water for five weeks one of them gave 2,367·8 cubic inches of water in two and one-half hours under eighty pounds pressure, "equivalent to 73·8 gallons per square foot of surface per hour—very far beyond the amount of percolation given by brick." "The sand here used was not of the very first quality, and the cement brick presented the appearance of great porosity."

Mr. Jas. B. Francis' experiments "showed that about seventeen and one-fourth gallons per square foot passed through a thickness of nearly sixteen inches of cement in

* John C. Goodridge, Jr., 113 East Twenty-fifth Street, New York.

twenty-four hours under a pressure of seventy-seven pounds per square inch." "Mr. Stauffer's experiments, made in the Dorchester Bay Tunnel, serve to throw light on the leakage through brick work. He constructed a bulkhead of brick, laid in cement, four feet thick, in a tunnel 10 x 10 feet. He found that under a pressure of seventy-two pounds per square inch the water percolated through at the rate of 120,000 gallons a day, or 1,200 gallons per square foot." "The experience on the Boston main drainage works proved that it was not practicable to build brick masonry that was water-tight under a pressure of sixty-four pounds per square foot.

"At the new Croton Reservoir, New York, water under thirty-six feet head was found to percolate through twenty-six inches of brickwork and four feet of concrete."*

When water was let into the Vanne Aqueduct in the spring of 1869 the inspector, M. Belgrand, certified that "*Impermeability appeared complete.*"

This conduit is built for miles of béton-aggloméré, composed of sand and cement. The pipe is circular, six and one-half feet in interior diameter, with a thickness of twelve inches at the sides at the water surface, and nine inches at top.

These results show a great range in the amount of percolation, due mainly to the size and character of the ingredients and the manner of mixing.

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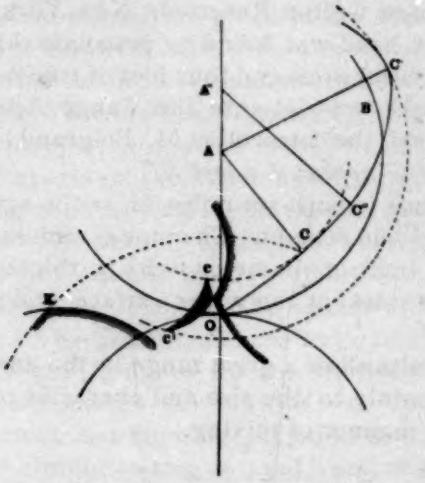
* *Vide Report on Washington Aqueduct Tunnel*, p. 21. House of Rep. Fiftieth Congress, Second Sess. Report No. 4,142.

THE CUSPS OF THE GEAR-TOOTH CURVE.

GEORGE B. GRANT, Lexington, Mass.

In designing gear-tooth curves, the flank of a pinion tooth formed on a pitch line that is smaller than a certain limiting size will be found to have a troublesome convolution consisting of two cusps. At each cusp the curve suddenly reverses its direction, and all tooth contact is impracticable beyond the first one.



This happens with any form of tooth curve, although sometimes in disguised form, and the only remedy is to avoid using pitch lines that are small enough to have the defective tooth. If smaller pitch lines must be used, the trouble must be avoided by cutting down the tooth until the cusp is removed.

If the curve is constructed by points, as is always possible, the cusp may be located, but the method is tentative, tedious and inaccurate. The following method will be found to be simple, exact, and of universal application.

In the figure *OCC'* is the line of action of the tooth system

that is in use, and it is required to locate the cusps of a tooth on the pitch line *OB* from the centre *A*.

From the given centre draw an arc *Cc* internally tangent to the line of action at *C*, and the first cusp will be normal at *c*. From the same centre draw an arc *C' c'* externally tangent to the line of action at *C'*, and the second cusp will be tangent to it at *c'*.

When constructing a tooth on this pitch line, the flank must end at the first cusp *c*. Furthermore, the curve of the face of any tooth that is to run with the gear must end at the point *K* on the arc *CK*; for, if it is extended further it will interfere with and cut off a part of the working flank of the gear tooth.

To determine the position of the centre of the smallest pitch line that will avoid the cusps altogether, find by trial the required centre *A''* from which but one tangent arc can be drawn to the line of centres at *C''*.

On the Value of Technical Training, and the Teaching of Drawing and Hand-Work in Public Schools.

By Edward Combes, C. E.

[*Companion of Most Distinguished Order of St. Michael and St. George, Officer of the Legion of Honor, and President of the Board of Technical Education of New South Wales, Australia.*]

It may be well to introduce this important and interesting paper to American readers by a few words concerning its author and the circumstances under which it was written.

Hon. Edward Combes is an engineer of ability and distinction, among the earliest who sought in the antipodes opportunity to wrest from nature her secrets and her treasures. Going to the Colony of New South Wales as a mining engineer, equipped not only with a technical and practical training as thorough as his native England could afford, but also with a wide and varied polite education, he was

thrown at once into those hardships and dangers, and that necessity of encountering emergencies and overcoming obstacles, which characterized early Australian days. His skill and force of character soon won for him the important position of Government Engineer of Mines; and as his clear judgment became more and more conspicuous in days of turmoil, he was elected member of the Colonial Parliament. He afterwards accepted the important portfolio of Minister of Public Works, at the time when of all others competence and reliability was demanded by reason of the imminence of war between England and Russia, which would mean ruin for the then defenseless city and harbor of Sydney. His name is thoroughly identified with the fortifications and the railway system of the Colony. In 1878 he was chosen as the fittest person to represent his government and country at the Universal Exposition in Paris, where he was made one of the Jury of Award. During that year and part of 1879, Mr. Combes—who received from the British and French governments, in recognition of his ability and services, decorations which he honored in accepting—travelled through the greater part of Europe collecting upon the subject of technical education information intended to shape the coming school system of New South Wales; and visiting this country extended his inquiries with a thoroughness which those who met him and those who have read his admirable and exhaustive report upon the subject* will remember. It was my good fortune to be in almost daily contact with Mr. Combes, during the year or more in which these inquiries were extended in Europe and America, and I take pleasure in testifying to the earnestness and thoroughness with which each system was examined in the most trifling details of its application, and through the widest results which it produced.

Adding to his many attainments that of being a color artist, whose productions have received medals wherever exhibited, and whose ability in this line was recognized by his election as President of the Society of Water-Color

* *Report on Technical Education.* Official Document, Legislative Assembly, New South Wales. Sydney, 1887.

Artists of New South Wales, Mr. Combes can view this question of technical education, and particularly the matter of drawing and handwork, from more sides than any other engineer of my acquaintance; and the eminently practical character of his private and public occupations precludes his entertaining any visionary views upon the subject. As artist and educated gentleman, as engineer having also large mining and manufacturing interests, as legislator and as Minister of the Crown, Mr. Combes has based his opinions upon thorough knowledge of every aspect of the case.

After examining the subject thoroughly, we must conclude with him that to permit any child to grow up with but one side of his nature developed, is a wrong done to him and to society at large. If we do not *put the whole boy to school*, we are lessening his earning powers, adaptability and capacity for happiness and usefulness. If, after knowing the facts in the case, we allow to remain dormant or become dwarfed, any faculty, which has been implanted in the young beings entrusted to us for development, we are unfaithful stewards, incompetent and criminally-negligent guardians, meriting punishment and reproach. ROBERT GRIMSHAW.

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No apology is needed for the subject of this paper. The education of the artisan and mechanic has occupied the attention of the greatest statesmen, as well as that of the most distinguished and eminent educationalists, throughout the whole of the civilized world, for a considerable number of years. Inquiries have been made by boards, commissions and committees appointed by nearly all the leading governments of Europe and America, as to the advisability of technical teaching, and in every case the conclusion arrived at has invariably been the same, viz: that its importance and utility could not be overrated and that it was the absolute duty of their respective governments to provide such instruction in the best possible manner. This has been carried out with greater or less good results; and my object is to bring before you, in as concise a manner as

practicable, the existing facilities, in actual operation, for imparting this class of instruction, and the general character of the primary education given in different countries with regard to its connection with the technical training necessary to afford the young such opportunities of acquiring that characteristic knowledge suited to the works and manufactures belonging to the particular district in which the school is situated.

While no real difference has existed among the advocates of technical teaching as to its general advisability, there have been a variety of opinions as to the manner or method of imparting it. One great question is with reference to apprenticeship schools. It is contended on the one hand that the old system of apprenticeship has completely broken down, and that consequently it behooves the state or the municipal government to teach the various trades in schools instituted for that special purpose. On the other hand it is stated that these trade schools are objectionable, on account of an expense not warranted by the results, and, moreover, that properly-equipped technical schools for every trade would practically be an impossibility. They also argue that such schools are not thoroughly effective, as improved methods and machinery are being daily discovered and applied, and consequently, that such schools could never keep pace with the factory, however perfectly the school might have been established in the first place. That the work accomplished would not be real, but of a very mediocre class, and that for want of association with real workmen, the school-taught artisan would be unable to commence as a skilled workman. There is much to be said on both sides, for while there can be no doubt as to the utility of apprenticeship schools for turning out scientific and highly-skilled workmen, eminently fitted for foremen, managers or proprietors of industrial works, the cost of training in these institutions is too great altogether, for the system to be applied to the masses. There can be no doubt that there is room for many modifications of the systems, and that more economical arrangements will be made in the future development of these establishments, which are numerous in Europe and con-

stantly increasing. They have proved their value over and over again in forming the most thoroughly trained artisans in most kinds of skilled labor, both in the practice of the art and in the knowledge of that science which underlies it. I may mention here that the success which has attended the industrial schools, established by law in France, Belgium, Germany and Switzerland, to give technical instruction to the masses, who have to live by the work of their brains as transmitted through the work of their hands, has been simply marvellous. It has been positively proved that the technical or practical work never injuriously affects the theoretical studies, but that, on the contrary, the manual work acts as a stimulus in the subjects of descriptive geometry and industrial drawing. This affords independent and direct testimony that the mental and physical powers are in direct accord, and can be simultaneously or concurrently educated with advantage to both.

But whatever may be the differences of opinion with reference to apprenticeship schools or manual training, there are none existing as regards the necessity of teaching drawing, which is the true and solid foundation of technical training. Ten years ago I advocated the simple principle that drawing should be taught in all the elementary schools. In my opinion a child should commence drawing, when learning his alphabet; to learn the name of a letter, and at the same time to imitate its shape from a model, enables the child to learn reading, writing and drawing, at one and the same time. The child learns far more quickly than he possibly could if he were taught separately, for the one helps the other; the eye and hand are brought into unison from the first, and once this is firmly established everything else comes easy.

The importance of drawing in industrial education cannot be overrated. It is the foundation of all the constructive arts. No industries can wholly dispense with it, and its exercise instructs the eye and hand to travel together. It is an essential aid to every class of artisans, while it instructs and improves both mind and body in its imitation of nature. It has often been called a universal language common to

all people of every nation. It is therefore clear that it should be commenced at the very earliest period, so that from the beginning of the child's tuition his eye and hand should thoroughly understand each other.

I say that no difference of opinion exists as to the necessity of teaching drawing at the earliest age, and from my own knowledge, I can state that a child learning his letters in the way I have above stated, on the three subjects at the same time, certainly learns to read and write more quickly than he otherwise would. I am happy to say that drawing has been made a branch of primary education in almost every system of elementary public instruction, and is now considered as necessary to a child's education as writing. It is no longer optional, but a required study. Its adoption is no longer an experiment, but an undoubted established fact. This must be honestly considered and attended to by the teachers of state schools. Many public school-teachers have never had the opportunities that are now given in normal schools and training colleges, to acquire that freedom of hand so necessary to the skilful artist, therefore they should take every opportunity to improve themselves in free-hand drawing. I find, wherever I have been, that generally the teachers are making the most strenuous efforts to carry out the instructions of the school boards, and every year will make a marked difference. The teachers have themselves become convinced of the necessity of teaching drawing from the earliest age, and consequently energetically endeavor to qualify themselves to impart the required instruction. At the present moment a great movement is going forward. A school training is required that will give better results in the every-day work of life than have hitherto existed. Drawing must be taught, and this must be done honestly, and not in any half-souled manner. The teacher must throw himself, or herself, into the subject enthusiastically, and then proportionate progress will be made. It must never be forgotten that the practice of drawing renders the pupil more apt, and better able to receive any subsequent industrial training, no matter in what branch of applied art, or whatever may be the industrial occupation.

It should constantly be borne in mind that the shorter time required to reach the position of a skilled workman, is a direct money gain to the State, fully sufficient to compensate the cost of the education. Froebel says that "drawing, painting, and modelling must necessarily be considered as a part of the general comprehensive education and training of man. They must be early treated as actual objects of the earnest school, and not be exposed to an accidental, worthless and fruitless and wanton arbitrariness; neither with the view that each scholar becomes an artist in some kind of art, and far less with the view that each scholar will be an artist in all branches of art, both of which nullify themselves; but with the definite view that each man may be raised to the point of developing his nature faithfully, completely, and on all sides; that he can raise himself to the point of recognizing the all-sided and all-powerful nature of man; but especially, as has been already stated, that each man understands how to perceive and to value the results of genuine art."

In bringing up a child in the knowledge of what is good and true and beautiful, we find that the study of drawing has immense advantages directly valuable as educational influences, and where the greatest attention has been paid to this principle, there also we find the greatest practical skill. The educating power possessed by elementary drawing is not doubted, and the great accuracy which drawing requires affords the best possible practice to the eye and hand, while of great value in training the mind to be observant, judicious and active. Imagination precedes reasoning, therefore the imagination should be cultured in primary education in such a way as to occupy a prominent place. We know that nothing is more attractive to the imagination than the beautiful. The sense of the beautiful is called *taste*, and should be accorded a first place in every system of instruction, more especially in primary instruction, and in the teaching of poetry and art; for, if education in the first place proceeds by images and realities, we should make use of them, by making them the vehicles of teaching the sublime and the beautiful.

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It has been well said that beauty is another word for education, and the connection of culture in the beautiful, with culture in morals, is fully apparent. In the recognition and the feeling, the loving and doing of the beautiful, coarseness and vulgarity, and tendencies towards debasing and sensual enjoyments find a countervailing power. The virtues especially developed by the study of drawing are persevering industry, love of unobtrusive right action, order, decency and purity. Goethe says: "The importance of instruction in drawing as a part of education will best appear when we consider that by means of that acquirement we gain an increase of beautiful and noble pleasures derived from the external world. The whole realm of form and color opens to man; he acquires a new mental organ; he receives the most delightful ideas and learns to recognize, to respect, to love and to enjoy the beauties of nature. Nothing gives the same amount of true happiness as art. Why, therefore, should not the masses be taught to obtain the salutary influence which it gives to those who have cultured tastes and a love for the beautiful, and who can appreciate to the utmost, by sight and hearing, correct proportions and divine harmonies." The man who has during a certain number of hours of the day to labor to gain his livelihood would surely gain the greatest consolation and solace in being able to see and understand the beauties of nature, and endeavor, by his own hand, to reproduce what he sees in clay or in colors, or simply in black and white by his pencil. Impressions that we obtain by our sense of sight imprint themselves upon the brain, and where preconceived ideas are wrong, they are instantly changed for our benefit by the correct judgment of the eye. It is, therefore, universally admitted that drawing should occupy a most important position in primary instruction, and that, when taught as it should be, it not only gives the facility in a greater or less degree to represent the various forms which occur in almost all trades and professions, besides being of inestimable value in the work of ordinary life, but it gives to all that correctness of eye and taste without which the true sense of the beautiful can never be thoroughly understood. In archi-

tecture, as in sculpture and painting, drawing is at once the instrument and the language. "To know how to draw," says Michael Angelo, "is to have the compass in the eye." The geometrician wants the compass in the hand, but the designer and painter want it in the eye. In the first place, mental calculation is required, while in the second there is an immediate intuition in a single glance. It is usual to speak of different systems of art education as the French, South Kensington, German or American methods, whereas in none of these countries is there any hard and fast, or even any comprehensive system of giving instruction in art for the public schools. As a matter of fact there is no absolutely national system of art education. When any of these so-called systems are taught, they are found to be the method of some talented teacher who personally gives instruction and advice to each individual pupil. It will be impossible here to describe the various plans adopted by different teachers, but I may mention that the one great common difficulty is in qualifying the regular school-teacher to impart art instruction, and the only practical way out of the difficulty is to encourage teachers to attend training schools, whose classes shall be open to teachers during the ordinary vacations. I am aware that this has been partially done here, as well as in many localities in Europe, with excellent results. It stands to reason that once the ordinary school-teacher, who has the confidence of his pupils, is capable of cultivating a perception and love of the beautiful in their minds by means of drawing, half the work will be accomplished. To learn to draw will be no longer an arduous task, but a pleasurable recreation in which the children will delight.

In Germany the teaching of drawing has undergone considerable change within the last few years, chiefly owing to the admirable teaching of Mr. Jessen. His success became most remarkable. Mr. Jessen was a civil engineer of Hamburg, where he established, at his own expense, a special school wherein to experiment with a method he had conceived for teaching drawing. His first trials were so extraordinarily successful that the municipal authorities of

Hamburg took the school into their own hands and voted for its maintenance £3,500 ($17,500) annually. This went on until 1875, when, on account of the ever-increasing number of the pupils, the municipality erected a new school, to which a museum was attached, costing £150,000 ($750,000), and at the present time there are over 2,000 pupils receiving instruction. Mr. Jessen has been appointed the art director of all the municipal schools, so that his method of teaching might be generally adopted.

This method appears to consist less in the innovation of any new scientific means of teaching the principles of drawing, than in giving the pupil, individually, that particular and special instruction which the necessity of his trade or profession requires. The time of study is not fixed, and the pupils stay at school three, four or five years, according to their aptitude in acquiring the necessary instruction. Often the very intelligent ones obtain proficiency in two years. All the courses take place in the evening. The first half of the first year is exclusively consecrated to the study of the primary elements of drawing, such as are generally taught in all the schools; but drawing from the flat is absolutely forbidden. Every lesson is drawn from an object. In the second half of the year professional drawing is commenced, and as soon as the pupil really knows how to draw, his work is chiefly confined to models which apply to his particular profession. In the following years the professional work and general artistic work are about equally divided, and one day in the week the work is exclusively professional, under the direction of a working foreman. This class is often held in private workshops, to teach the application of the general principles learnt at school. Private workshops had to be used, as, at the time of my visit, the government had not organized any manual professional schools. The great singularity of Mr. Jessen's method is that the pupils do not receive their instruction in class, but that each one, individually, receives a personal intimate instruction, varied in accordance with his temperament and aptitudes. The professor is always in attendance in the school, where he is continually engaged inspecting the work of the pupils,

reasoning with them and giving them judicious counsel; in short, he follows step by step the work of each student placed under his direction.

It is this individual instruction that causes the great success of Mr. Jessen's method. It enables the teacher to take into particular consideration the capacity of each particular pupil. This is a most weighty circumstance, because, in drawing solid objects, the clearness and liveliness of the perceptive powers, the accuracy of the eye, and dexterity of hand must be brought out. These qualities are very important, and are found to differ exceedingly in different individuals. By *individual* treatment, those in every way naturally gifted need not be held back, while the weakest need not be dragged along in order that the medium, forming the majority, should not suffer.

The question as to the best method of giving a technical education to the youth of a country, is the great problem of the age. Upon its proper solution the prosperity of a country as regards its agricultural, industrial and commercial relations may depend. It concerns the working population, the masses of the people, over whom it is the duty of the government to watch with an ever-increasing solicitude. It is exactly this class of instruction which enables the future man or woman to earn a living, and by producing a good class of workmen to place the country in the best industrial position. The great desire of all nations is to produce work by which their respective populations may live, and this desire extends itself year by year in direct proportion to the relative increase of population. It is not only a social but a political question of the highest importance. To place the people of any country in a position to successfully compete with the rest of the world, is the object of all who desire their country's good. The imperative necessity of comparatively placing the people in this position is self-evident, and no one dares to question its practical utility. The matter to be considered is, how to do this in the most practical and effective manner.

The old system of making workmen was by the process of apprenticeship. This was the only road to learn a trade.

The apprentice paid a fee for instruction and received his board and lodging as an equivalent for his work. He was of the family of his master, his friend, and often became his son-in-law. There was every inducement for a master to teach his apprentice, accordingly apprentices were carefully instructed, and there existed a sufficiency of good artificers in proportion to the demand for their work. Now, however, this is altogether changed. The invention of machinery and special tools has destroyed the old workshop and diminished small factories, and the industrial system of the country has been revolutionized and reconstructed. This reconstruction has its good as well as its bad side. Manufactured articles of all kinds are incredibly cheaper than they used to be, and there is for all who choose a greater chance to enter the class of skilled artisans. On the other hand, the mechanic is kept week after week and year after year at one particular branch of the trade, such is the necessary result of a division of labor. There can be no doubt that this monotonous employment and specialization of labor tends to the degradation of the workman and to a diminution of the art-value of his work. The manner, therefore, of educating young artisans daily becomes more important, and an opinion is steadily growing up that our elementary training, whether for rich or poor, is still exceedingly incomplete, and will never become fitted to the wants of the time until it has undergone some radical modifications, and I thoroughly believe that these will take the form of manual training.

If we divide the future occupations of the youth of all countries into agricultural pursuits, industrial production and manufactures, distribution and commerce, together with the learned professions, we find that the teaching is not in accordance with this division, but that in the provisions made by the public or state schools, it would seem that all our young men were to become parsons, clerks and lawyers. There is nothing industrial in the curriculum or anything really adapted to the manufacturing requirements of the country. It indicates that educationists have begun at the wrong end. That the culture of the masses should

precede their industry, whereas it has been universally conceded that the ornamental should wait upon the useful. It remains, therefore, to instruct the masses in such a manner that, while giving them their ordinary tuition in reading, writing and arithmetic, they may learn to use their hands as well as their heads.

The question as to the possibility of organizing workshops in primary schools has been often considered. The decision arrived at has been generally in favor of the principle, but that the practical teaching of different trades would be next to an impossibility. To carry out a system of manual training in primary schools, it is necessary to generalize and to teach that class of work which is common to all handcrafts, and useful to everyone whatever may be his social condition; work just sufficient to develop manual dexterity, and which will also serve for purposes of recreation. This is not at all theoretical. The system has been applied in hundreds of cases, and given results eminently satisfactory.

The work adopted as the most convenient is that which is the most simple in its character; the easiest class of carpentry and wood turning. With boys there seems to be an innate longing to use carpenter's tools, and this is quite sufficient in the first instance to set in motion the constructive faculties, and to develop manual dexterity. Besides, these elementary exercises do not require large workshops or expensive tools, but can be taught in the play sheds of ordinary primary schools. In France, handwork in schools is now made compulsory.

I must, however, find space for noticing what has been done of late in Sweden, more especially in the training of the ordinary school-teacher, both male and female, so that they may be qualified to impart the knowledge of manual work to their pupils. In the Swedish language this handwork is called *slöjd*, a word which has no exact equivalent in the English language.* It is an old national word, coming from an epoch when nothing but hand tools were used. It

* Perhaps our word "sleight" still bears about the same meaning. R.G.

does not mean any handicraft, but implies a general sense of dexterity and cleverness. Thus, speaking of a farm laborer as a *slöjdare* means, that while he is simply a laborer, he is a handy man and able to use and repair the common tools and implements in use on the farm.

This simple work was originally taught to children by their parents, for it was customary with the peasant to make and repair any furniture or tools required by the family. This was generally done during the long winter evenings. When factories sprung up, making cheap articles of iron and ware to replace those wooden utensils, the desire and the aptitude for making them at home were by degrees lessened and, indeed, almost altogether destroyed. The workman degenerated to such an extent that the government instituted an inquiry into the cause, when it was found that out of twenty-four districts only five retained anything like the habitude and custom of this cottage labor. The laborer was no longer a *slöjdare*, and his production having ceased, the country lost a considerable source of wealth. It was thereupon determined that this manual training should be taught in all the primary schools.

The great difficulty was the teacher. It was necessary to train them, and here a patriotic gentleman, named Abrahamson, came forward, and not only established a normal school for the purpose, but duly endowed it, placing it under the direction of his son-in-law, M. Solomon, who was also one of the first and most fervent propagators of manual work in primary schools. In conjunction with the founder, this gentleman has carried forward the grand work with the greatest enthusiasm, and their wise lessons cannot possibly be studied without appreciating the important results that have been achieved by the teaching of handwork in primary schools.

It has been directly and definitely proved that this manual teaching must not be confided to artisans without any knowledge of pedagogy, therefore it goes without saying that in future handwork should be taught in all normal schools, and no appointment of teacher made to any school, unless he or she be duly qualified to impart this knowledge.

When manual work is universally taught in all primary schools, how much more efficient will become the professional and apprenticeship schools. The pupils having already gained that dexterity so requisite to all handicrafts. Moreover, the habile workman will be made in less time. He will be as clever and experienced at 18 years of age as otherwise he would have been at 21; thus three years will have been saved, and allowing a man able to work at his trade thirty years, there will be an increase of one-third in the producing power of the state, which, in a money value, would more than compensate the government for any sum it might expend in the complete organization and perfection of a thorough system of technical training.

The training now instituted in America, Belgium, England, France, Germany, Holland, Russia, Switzerland and many other countries is chiefly of a secondary character, the apprenticeship and professional schools are exceedingly numerous and constantly increasing. Time will not permit any detailed description of these schools, of which, perhaps, the Ecole Diderot, of the Boulevard la Villette, in Paris, is the best typical form, and young men leaving it readily obtain wages of from four to seven francs a day.

The opportunities and facilities for the acquisition of technical knowledge have been far greater in France than in any other part of the civilized world. In France, every instruction can be easily obtained. From the National School of the Fine Arts to the rudimentary class at the primary school, all is free, and throughout the whole of the country there are departmental schools, both in the daytime and during the evening, giving instruction gratuitously in every branch of art and design, and, as I have mentioned before, manual training is compulsory. This explains at once the reason that France exports millions, nay, hundreds of millions, of value in commodities, of which the chief value lies in the labor consumed in making the article, and every nation contributes to her prosperity in purchasing these commodities. The immense sums spent by the French government in providing the technical instruction for the production of workmen capable of this class of work,

are amply compensated by the wealth obtained through the contributions of capital by the entire civilized world.

With the progress and development of a nation, there ever follows a fiercer and fiercer competition in matters pertaining to labor. It therefore follows that for any nation to hold its own, the highest technical skill will be necessary. To obtain this skill the rising generation must be instructed, not only in the ordinary subjects of education, but also in the use of simple tools, so that manual dexterity may be obtained at the earliest possible period. The education that will compass this must necessarily bring about another desideratum. Children who have been taught the use of tools will not in after life look down upon those who labor with their hands. They will have been taught through the equality that exists in the school and as bench-mates in the work shop, that all labor is honorable, and that good fellowship should always exist between them as fellowmen, a feeling which cannot but conduce to the general diffusion of happiness, and consequently to the good of the commonwealth.

HARBOR BAR IMPROVEMENTS.

By L. D'Auria.

In an article published in the Franklin Institute Journal for July, 1889, under the above head, Prof. L. M. Haupt, C.E., shows in a very brilliant manner the momentous importance of removing bars which are formed by the forces of nature at the entrances of harbors, a fact, which has always been recognized by commercial nations, but believed by Professor Haupt to be disregarded by the Government of the United States, because this Government has not yet adopted his plan for removing such bars.

The professor wants the abolition of parallel or nearly parallel jetties as means to improve harbor entrances, and he quotes the highest English authorities on the subject. These authorities seem to discourage such jetties, but, as yet, do not feel competent to suggest new means; and it is

difficult to understand why they have not yet adopted those proposed by Professor Haupt, as set forth in his pamphlet, entitled: *The Physical Phenomena of Harbor Entrances. Their Causes and Remedies. Results of Present Methods of Improvement*, which was crowned by the American Philosophical Society, December 16, 1887, with the award of the Magellanic Premium.

In this pamphlet, right on the first page, the author says:

"Before any radical or permanent improvement can be effected, it is necessary that the forces operating at any point should be fully understood, and, so far as possible, be measured."

Let us see how Professor Haupt understands these forces, and whether he has made any attempt to measure them.

He claims (page 20, above-quoted pamphlet):

"The enunciation of the principle that the cause of the angular movement of the ebb stream after egress is due to the general form of the exterior coast line, which causes a racing of the tidal crests, from the outer capes toward the bight of the bay, and that the *flood components thus generated are the principal forces* which build the bars and shift the inlets. This incessant semi-diurnal action of the flood is the *controlling element* in the forces affecting the magnitude and position of the bar. Storms and winds may modify and shift the deposits, but eventually the flood re-establishes the original conditions." (The italics are his.)

As the crest of a tidal wave moves by propagation, *the racing of the tidal crests, from the outer capes towards the bight of the bay*, cannot mean anything else but the propagation of two tidal waves in such directions. In fact they must be the waves which produce what, on page 7, he calls *flood resultants*.

On page 8, he says:

"It now remains to determine why this resultant should be sometimes from the northeast, and at other times from the southeast. This leads at once to an examination of the phenomena attending the approach of the tidal wave and

the position of the cotidal lines with reference to the coast line. For this purpose there are available the general cotidal maps of Professor Guyot, and the more detailed maps of Professor Bache, accompanied by the tide tables of the Atlantic coast, as contained in the *United States Coast Survey Report.* Meagre as these data are, they are yet sufficiently abundant to confirm the existence of the alleged resultant movements, and to verify in the most satisfactory manner the reliability of this method of determining the forces by their effects."

This is certainly a very startling conclusion reached from *the position of the cotidal lines with reference to the coast line*, for Professor Bache himself in commenting about such lines, says:

"The chart shows how simple the system of cotidal lines is in the three bays running nearly parallel to the shores" (*Coast Survey Rep.*, 1857, p. 346). In other words, we know that the tidal wave is propagated in a direction normal to the coast line and not parallel to it, as Professor Haupt concludes. But the professor in a correspondence on the subject says:

"This crest line cannot be supposed to have sufficient prescience to advance or retard itself at a considerable distance from shore, preparatory to rolling up on the beach normally."

Does he understand the meaning of the cotidal lines? It seems not; and yet Professor Bache says: "How simple the system of cotidal lines is." If Professor Bache is that authority on the subject of tides, which scientists and investigators consider him to be, certainly Professor Haupt needs schooling on this subject. The evidences are that Professor Haupt has an altogether erroneous idea of the tidal wave, for in the above quoted correspondence speaking of the tidal wave he says:

"It meets an obstruction, its oscillations are restricted by the shelving beach, the wave is tripped and broken, and the surf churns up the sand."

Here Professor Haupt degrades the *tidal wave* to the rank of a simple *breaker.* Then he goes on to say:

"If the wave breaks normally the sand is merely rolled up and down the scarp of the beach, but if obliquely it is turned over and carried to a more remote part of the shore. The action is similar to that of an auger."

Here Professor Haupt evidently repudiates his idea, originally stated, of a *littoral movement of water* in the direction of the shores. He no longer doubts the *prescience* exhibited by the tidal wave in preparing itself to roll normally upon the shore; he has been made to understand differently the forces which, he says, *should be fully understood before any radical or permanent improvement can be effected;* all this in the hope that the tidal wave will be capable of rolling sand up and down the beach in a zig-zag manner.

In the light of the foregoing criticisms, it is difficult to appreciate wherein Professor Haupt is entitled to "*the merit of having not only clearly perceived and distinctly enunciated the laws concerned as the basis of his argument, but also to that of proffering, in connection with the statement of those laws, an invention contributive to the interests of navigation,*" etc. (see *Report of Committee*, American Philosophical Society).

However, as the professor tells us that the *forces operating at any point should be fully understood, and, so far as possible, be measured*, we thought to measure them for him, having already assisted him in understanding them through a correspondence deposited with the Secretary of the FRANKLIN INSTITUTE already cited above, and which is accessible to the reader on application.

The method employed for such measurement is as follows:

Assuming a rise and fall of tide of four feet, the mean velocity of the flood current in a direction nearly normal to the shore, at say 100 feet from it, would, in ten feet mean depth of water, be $100 \times 4 \div 10 = 40$ feet in about six hours; or nearly seven feet per hour. Make it ten feet per hour. Then, since it is known that it takes a mean velocity of one-half mile, or about 2,500 feet per hour to just raise sand from the bottom (see *Trautwine*, edition of 1885, p. 270), and according to Professor Haupt's own statement the transporting power is proportional to the sixth power of the

velocity, a mean velocity of ten feet per hour would possess a transporting power equal to $\frac{1}{244,000,000,000,000}$ of that required to begin the transportation of sand.

When such utter impotency of the flood tide to build bars was shown to the professor, we expected that he would become converted to the fact that only wind waves or breakers can do such work. But no, he sprang up from this, and in his bewilderment he appealed for help to the keepers of life-saving stations through the Hydrographic Office; trying to establish, no more the auger-like action of the tide which he thought to have discovered, but an actual littoral current produced by the tide, of such power as to drag ships on the bottom of the ocean! Like a modern Faust, he seems to have cursed science and given himself to the *world.* We see him again in his last article, *Harbor Bar Improvements,* upbraiding *the people of the State of Texas for appealing urgently for the rapid completion of the project* at Galveston Bay, which, according to his ideas, *will violate the fundamental requirements of the greatest freedom of influx to the flood tide that there may be a full prism for ebb scour.* Evidently Professor Haupt has yet to learn the relation existing between flood and ebb at the entrance of a tidal basin as that of Galveston Bay, and the people of the State of Texas may well be congratulated for not sharing the professor's views.

Let h_0 represent the average depth of the entrance to a large tidal basin at mid-tide; x, the height of tide above h_0 at any instant of time; y, the corresponding mean width of the entrance at such time; and g, the acceleration of gravity. Then the cross-section at any time will be

$$\Omega = y\,(h_0 + x) = y h_0 + y\,x;$$

and the mean velocity through this cross-section can be computed by considering the water in the first part, $y\,h_0$, to remain stagnant, while the water in the second part, $y\,x$, moves with the velocity of propagation of the wave which is known to be expressed by $\sqrt{g\,H}$, in which H represents the mean depth at high water for the whole basin.

Then the mean velocity through the whole cross-section Ω will be:

$$u = \frac{x\, y\, \sqrt{gH}}{y\,(h_0\, u + x)}$$

or simply

$$u = \frac{x\, \sqrt{gH}}{h_0 + x}$$

This formula shows very clearly that the mean velocity through the entrance of a large tidal basin is independent of the width. It shows also that at high water the velocity is a maximum, and at mid-tide it becomes zero, which accords very well with observations taken at the entrance of large tidal basins during flood tide. When x becomes negative, we have the mean velocity of the ebb current, which is also zero at mid-tide, and a maximum at low tide.

Applying our formula to the case of Galveston Bay, Texas, it can be seen that the jettied channel will, in ordinary circumstances, be scoured with at least the same velocity as now exists through the entrance to such bay, although the tidal volume is diminished considerably.

We cannot see, therefore, any violation of *the fundamental requirements of the greatest freedom of influx to the flood tide that there may be a full prism for the ebb scour*, in the case of the project of Galveston Bay, so severely criticized by Professor Haupt, and we once more congratulate the people of the State of Texas for urging the completion of such project.

ON CHENOWETH'S ELECTRIC CONDUITS.

[*Report of the Committee on Science and the Arts.*]

[No. 1419.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 29, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred for examination,

THE CHENOWETH ELECTRIC CONDUITS,

Report that: The invention belongs to that class of conduits in which the material of the conduit is packed while in a plastic condition, around one or more cylindrical cores, which are removed after the plastic material has hardened. The essential part of the invention is the nature of this removable core, which enables it to be withdrawn in long lengths. This core consists of a ribbon of galvanized iron, one inch wide and of a thickness equal to No. 27 gauge, which is wound spirally, forming a tube. This spiral tube is rendered rigid, either by being wound around a split wooden core, or by having paper glued around the outside. The plastic material is packed around these tubes and after it has set the tube is removed by pulling out this spiral band. When paper has been used to hold the spiral together, it readily tears, allowing the band to be removed. When wooden cores have been used, they are first withdrawn, after which the spiral band is readily pulled out.

Among the details of the system are the following:

When paper is used to unite the spiral into a rigid tube, the ribbon is first wound spirally on a mandrel, then covered with paper, which is glued fast to the outside of this spiral, and the whole covered with a water-proof varnish. The mandrel is then removed, leaving a thin tube, which appears to be quite rigid and capable of withstanding the pressure

due to the packing of the plastic cement of the conduit around it. These are laid in lengths and held in position while the cement for the conduit is packed around them. The ends of the one spiral ribbon are fastened to the beginning of the next, by a swivel joint. After a few days, when the cement has hardened, the spiral ribbon is pulled out at one of the manholes, tearing and thus removing the paper around it. It is claimed that long lengths of this spiral tube can be thus removed.

When this spiral tube is wound over a wooden core, this core is made in two semi-cylindrical halves, separated by a thin iron strip. The outside is painted with a mixture of clay, powdered soapstone and water. These are laid in lengths of fourteen to twenty feet, and after the cement is packed around them the wooden cores are withdrawn, after pulling out the strip of iron separating them. This leaves the spiral tube, which remains until the cement has hardened and is then withdrawn in long lengths.

The inventor claims that continuous lengths of 400 feet of spiral tube can thus be withdrawn. For removing this ribbon, the inventor states that he has a peculiarly constructed reel, by means of which the ribbon can be pulled out, wound up and untwisted in one operation.

For the material used for the conduits, the inventor prefers a mixture of one part of hydraulic cement and two parts of sand. The costs are given by the inventor as follows:

"The cost of constructing ducts by this method is narrowed down to the winding of the ribbon on the mandrel, the labor of removing the mandrels in the trench, of removing the ribbon from the duct and rewinding the ribbon on the bobbins. And as each part of the core is preserved and used an indefinite number of times, the cost of the core is charged to the cost of the plant. The winding of the ribbon is done on the spot as fast as wanted. The cost of drawing out the ribbon and rewinding on bobbins, using an ingenious device that removes all twists, is about one mill per foot. A duct, four inches in diameter, made of concrete, in the proportion of one of cement to two

of sand, can be made for six cents per foot, including entire cost, exclusive of excavation, manholes and openings."

The inventor claims that the advantages of the paper-covered tube is convenience, the cost being about the same.

The inventor gives the following comparative costs of materials for three forms of conduits. The estimate is for a conduit of four ducts, four inches in diameter, one foot long. For creosoted wood, six cents per foot per duct; for iron pipe, encased in concrete, eighteen cents per foot per duct; for his conduit, three cents per foot per duct. This does not include excavation, which is about the same for all. It does not include the cost of handling his removable core.

Your committee have examined samples of these removable cores, and portions of conduits made in this way, and are of the opinion that the invention is simple, ingenious, effective and inexpensive. Furthermore, an invention of an efficient removable core enables monolithic conduits to be made of hydraulic cement, whose properties are already well known. Unlike creosoted wood, it contains no substances which are likely to attack chemically the insulation or the lead armor of cables, and unlike iron it does not corrode. The results, therefore, which can be accomplished by means of this removable core, are unquestionably of value.

Your committee recommend the award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to Alexander Crawford Chenoweth, for his improved method of laying continuous electrical conduits.

[Signed] CARL HERING,
Chairman Sub-Committee.

RICHARD W. GILPIN,
CHARLES H. RICHARDSON,
G. BETTON MASSEY.

Adopted, June 5, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

THE SUBSTITUTION OF GELATINE IN PLACE OF COLLODION FOR PHOTOGRAPHY.

[*Report of the Committee on Science and the Arts.*]

[No. 1451.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

THE SUBSTITUTION OF GELATINE IN PLACE OF COLLODION FOR PHOTOGRAPHY, AS INVENTED BY DR. RICHARD LEACH MADDOX, AND FREELY MADE KNOWN BY HIM IN THE PAGES OF THE *British Journal of Photography*, SEPTEMBER 8, 1871,

Report that: They have carefully considered the subject and examined into the merits of the invention claimed by Dr. Maddox. They find that although gelatine had been employed photographically in a variety of ways, and although silver haloid salts had been emulsified successfully with collodion in photographic practice, prior to the publication by Dr. Maddox of his gelatino-bromide process, nevertheless the successful emulsification by him of silver haloids with gelatine and the perfecting of a working process, founded upon it, involved so much painstaking experimentation and investigation and was such a departure from old methods that it merits recognition on account of its marked influence on the progress of photography, on the enlargement of its practice, and the multiplication of its applications in technical and purely scientific directions.

The process, though affording negatives of good quality, was soon improved in regard to the quality and sensitiveness of the plates by different individuals, by the removal of the soluble salts, by heating to higher temperatures, by prolonged digestion, by the adoption of ammonia and by changes in minor details.

In consideration therefore of the novelty of the process and of its value, and of the publication of it without any reservation of rights, your committee recommend the award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to Dr. Richard Leach Maddox, for the substitution of gelatine for collodion in photography as accomplished by him.

[Signed] CHARLES F. HIMES,
Chairman Sub-Committee.

JOHN C. BROWNE,
JOHN CARBUTT,
SAMUEL SARTAIN,
JNO. G. BULLOCK,
F. E. IVES.

Adopted, May 1, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

[Extract from the *British Journal of Photography*, September 8, 1871.]

"Originally thirty grains of gelatine were swelled in cold water, then dissolved by heat, four drams of pure water and two drops of aqua regia being added. To this solution eight grains of cadmium bromide and fifteen grains of silver nitrate were added, forming a fine milky emulsion of silver bromide. Without further treatment this was spread upon glass plates and dried. The plates were tested by exposing them beneath negatives and gave a faint but clear image when developed with a plain solution of pyrogallic acid; intensification with pyro and nitrate of silver followed * * * So far as can be judged, the process seems worth more carefully conducted experiments, and if found advantageous, adds another handle to the photographer's wheel."

NOTES AND COMMENTS.

CHEMISTRY.

CANAIGRE. BY HENRY TRIMBLE.—The following account of a tanning material, which has several times in the past few years been mentioned as new, or as a possibility for the tanner, is undertaken with a view of relating what has been done toward developing this source, and at the same time calling attention to the fact that, if we encourage home production, we have in canaigre a material which gives promise of superseding the uncertain and much adulterated gambier.

Canaigre is found in large quantity in the sandy soil on both sides of the Rio Grande and northward over a large portion of Western Texas and New Mexico.

Its history is briefly as follows: It is said to have been used in tanning by the Mexicans for over two centuries. Our first information, however, dates from July 9, 1868, when a package of these roots was forwarded for Mr. John James, of San Antonio, Tex., to the Agricultural Department at Washington, together with a letter stating that Mr. F. Kalteyer, chemist, in San Antonio, had found them to contain thirty-two per cent. of tannin.

This sample was mislaid or overlooked until 1878, when it was reported on by the chemist.* This same sample was then found to yield 23·45 per cent. of tannin. A fresh sample was also procured and the tannin estimated in the still fresh root with almost identical result, after making due allowance for difference in moisture. The other constituents reported at that time need not claim our attention at present, further than to notice a considerable quantity of starch, 18·00 per cent.

Previous to this publication by the Government, Mr. Rudolph Voelcker, of Galveston, Tex., published† an analysis of roots gathered in July, 1874. He found 23·16 per cent. tannin, and proved the presence of chrysophanic acid and aporetin. He was not aware of the botanical origin of the plant, but supposed it to belong to the natural order Polygonaceæ. In 1879, Mr. Wm. Saunders‡ in his report on canaigre stated it was the *Rumex hymenosepalum* of Torrey, and furnished a lithographic plate of the plant in bloom.

At the New Orleans Exposition, 1885–86, in one corner of the section, devoted to products from New Mexico, were some of these roots, above which was the inscription, "A new tanning material."

It will be shown later that this exhibit, insignificant as it appeared, attracted the attention of at least one person.

In 1886§ a sample of roots sent to me from San Antonio, Tex., under the name of "Indian Root," was analyzed and the results published under the

* Report of the Commissioner of Agriculture, 1878, p. 119.

† An analysis of Raiz del Indio. *American Journal of Pharmacy*, 1876, p. 49.

‡ Report of the Commissioner of Agriculture, 1879, p. 364.

§ An analysis of *Aristilochia fœtida*. *American Journal of Pharmacy*, 1886, p. 113.

common name of "Yerba del Indio," from the impression it was the *Aristilochia fœtida* of the Mexican Pharmacopœia. This impression, however, was corrected by Prof. J. M. Maisch in the same issue, page 115. He suggested, and it has since been found to be correct, that this "Raiz del Indio" was the canaigre root.

That analysis fixed the amount of tannin at 11·66 per cent., but it was found that the root, which was not analyzed as soon as received, had commenced to decay and later it was completely riddled by insects. In this respect my experience differed from that of the Government chemist, who found no change after ten years.

Soon after the New Orleans Exposition, samples of two or three hundred pounds were sent to Chicago for experiments in a number of tanneries there. Mr. E. C. Denig, of that city, has devoted much time since then to studying this material, from its source in Texas to its application in the tanning of hides.

Cahaigre consists of heavy globular and fusiform pieces, from two to six inches long and one to three inches in diameter. Externally it is of a dark reddish-brown color, becoming, by age, almost black; internally it is from a bright to a brownish-yellow, according to age and amount of exposure to the atmosphere. When collected, the roots consist of clusters, resembling sweet potatoes. They are found near the surface or sometimes on top the ground, are rapidly dried and at a certain stage cut into small pieces. If allowed to get very dry, they become so hard as to resist any ordinary method of cutting.

From samples of the whole and chipped root, kindly furnished me by Mr. Denig, I have found 17·33 per cent. of tannin. This figure is rather lower than that obtained by other investigators, but the deficiency may be explained by my sample containing more moisture. Dr. H. E. Shucke* has found a total of 28·57 per cent. tannin.

The ground root is at present used in a number of tanneries, and has been found more closely to resemble gambier in its action than any other tanning material. An extract has also been prepared and used, which contains from forty to sixty per cent. tannin, and, it is thought, that in this form it will probably replace gambier.

Should the hopes and efforts of those who are engaged in the development of this material be realized, we will have a source of tannin which is said to be inexhaustible, and which will be the means either of bringing a better gambier into the market, or of driving it entirely out of use here. It is said that the dried and ground root can be delivered in any part of the United States at a price not exceeding three cents per pound. Thus, after a delay of twenty years, this root has reached that stage of practical application when a useful future may be predicted for it, and the persistent efforts of the past four years have every prospect of being rewarded. The presence of so much starch in a tanning material is, perhaps, without precedent, and there are good reasons why this is no disadvantage.

The properties of the pure tannin have not been investigated, and it is

* *Shoe and Leather Reporter*, Oct. 27, 1887, p. 862.

not known whether canaigre red or gallic acid is the product of its decomposition. Crystals have been obtained by agitating an aqueous extract of the root with ether, which do not resemble either gallic acid or catechin. This crystalline compound and the pure tannin are under investigation by me at the present time.

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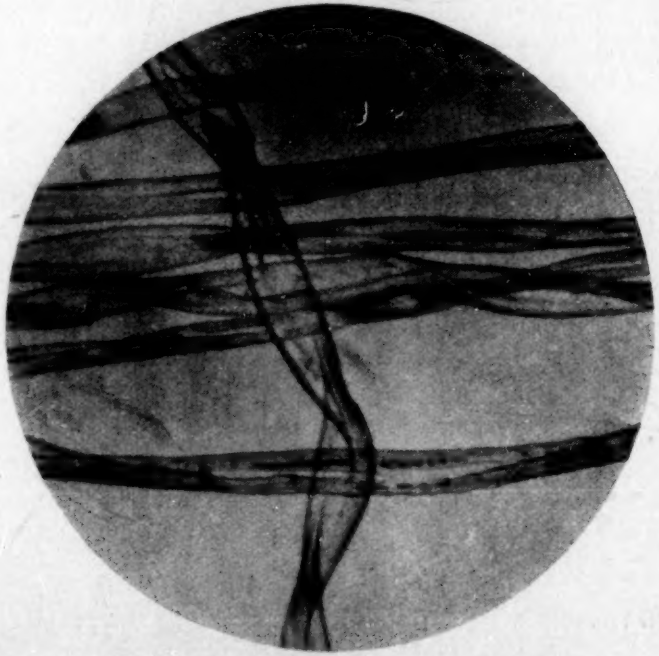

A.—Upland Cotton—Coarse and not very well developed.

B.—Upland Cotton—Raised from third-year carefully selected seed.

C.—Ozier Cotton from the Mississippi Delta—Fine, very strong and well developed.

D.—Ozier's "Silk" Cotton from the Mississippi Delta.

PHOTO-MICROGRAPHS OF COTTON FIBRES (DIRECT), SHOWING SPIRALITY, SIZES COMPARATIVELY, STRUCTURE AND OIL-CELLS.

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